Title: Model-agnostic characterization of post-merger signals from binary neutron star coalescences

Date: Sep 28, 2017 01:00 PM

URL: http://pirsa.org/17090062

Abstract: <p>The long-awaited detection of gravitational waves has provided us with another source of information about the Universe. In this talk I will give an overview of how we extract information from gravitational wave signals with a focus on signals for which we do not have a definitive and reliable model for what the signal looks like. In particular I will describe how we can analyze the signal emitted after two neutron stars have merged. I will describe how the information extracted from such a signal can be used to place constrains on the equation of state of dense matter.</p>

Model-agnostic characterization of post-merger signals from binary neutron star coalescences

Katerina Chatziioannou

Canadian Institute for Theoretical Astrophysics

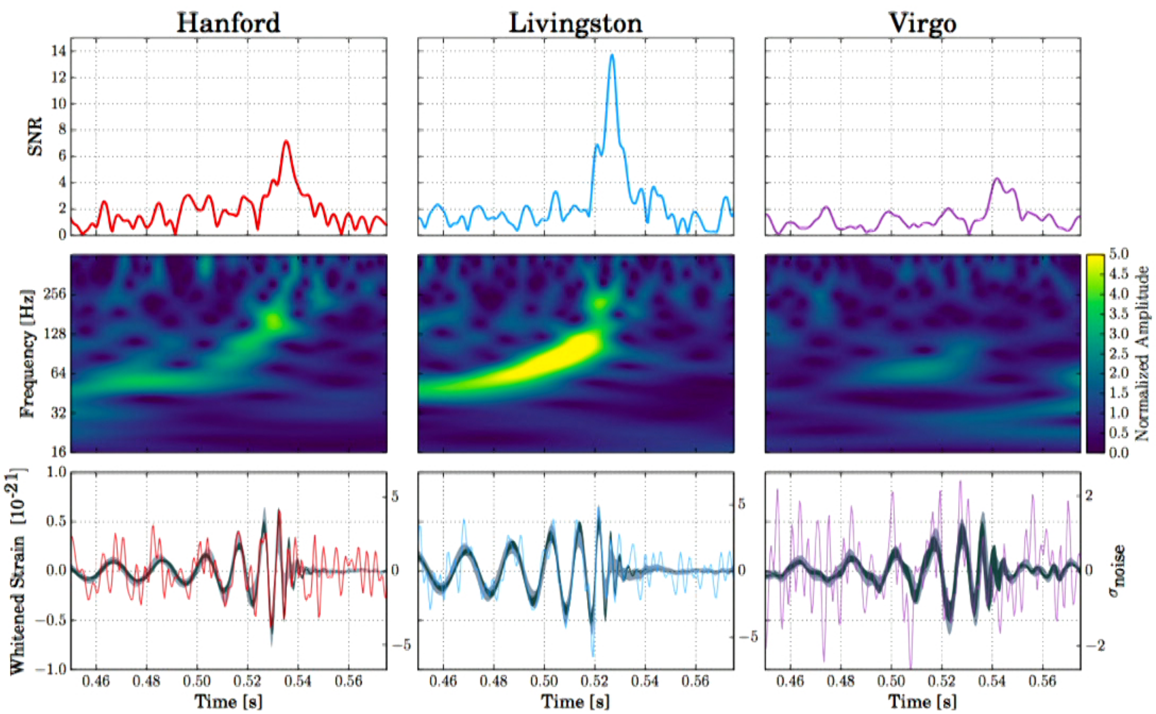
with J. Clark, A. Bauswein, H.-T. Janka, & N. Stergioulas

Perimeter Institute, 28/9/2017

LSC LIGO Scientific Collaboration

The 55-solar-mass elephant in the room

GW170814



Now with 50% more detectors

Polarization test!

LVC (LIGO-P170814)

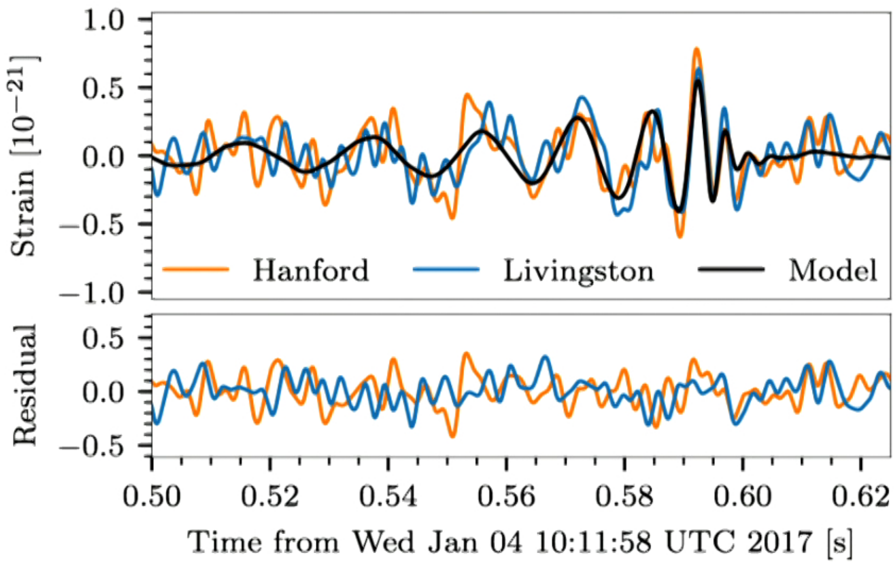
Model-agnostic characterization of post-merger signals from binary neutron star coalescences

LIGO Inference

$$p(h'|d) = \frac{p(d|h')p(h')}{p(d)}$$

LIGO Inference

$$p(h'|d) = \frac{p(d|h')p(h')}{p(d)}$$



LVC (PRL:118, 221101)

LIGO Inference

Likelihood for the data
(stationary and Gaussian)

$$p(d|h') \sim e^{-\frac{1}{2}(d-h)_i C_{ij}^{-1}(d-h)_j}$$

LIGO Inference

Likelihood for the data
(stationary and Gaussian)

$$p(d|h') \sim e^{-\frac{1}{2}(d-h)_i C_{ij}^{-1}(d-h)_j}$$

Prior for the signal

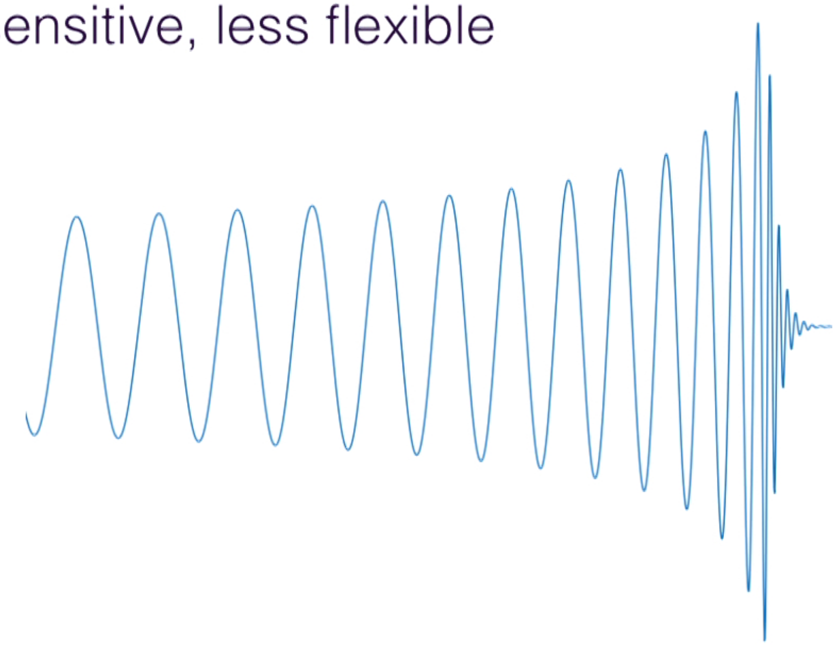
$$p(h')$$

Template-based analysis

Strong prior: most sensitive, less flexible

Template-based analysis

Strong prior: most sensitive, less flexible

$h' \rightarrow$ 

Generic analysis

Weak prior: less sensitive, more flexible

$$h' \to \sum^{N} w(\vec{y})$$

$$p(h') = \delta\left[h' - \sum^{N} w(\vec{y})\right] p(\vec{y}, N)$$

BayesWave

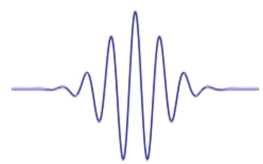
Bayesian model selection and parameter estimation

Wavelet decomposition of signals

Cornish, Littenberg (arxiv:1410.3835)

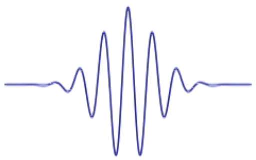
Wavelets

$$w(t; A, f_0, Q, t_0, \phi_0) = Ae^{-(t-t_0)^2/\tau^2} \cos(2\pi f_0 (t - t_0) + \phi_0)$$

$$h' \rightarrow \sum^{N}$$ 

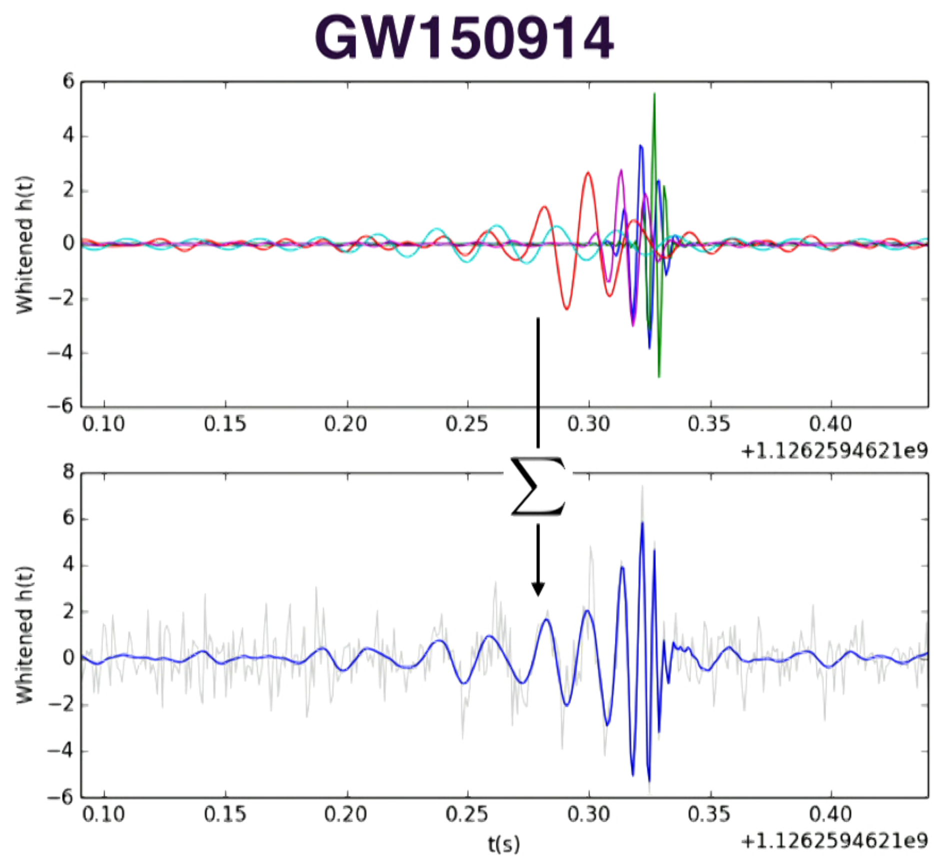
Reversible Jump MCMC

$$h' \to \sum^{N}$$



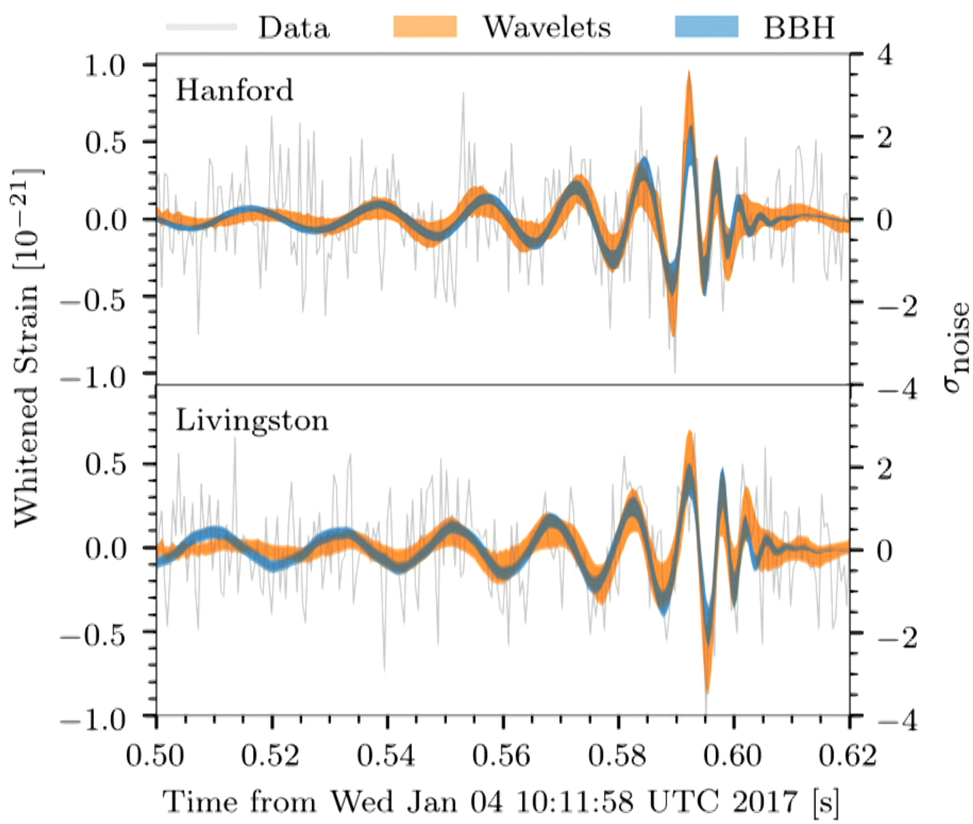
Robust against overfitting

One sample from the Markov Chain

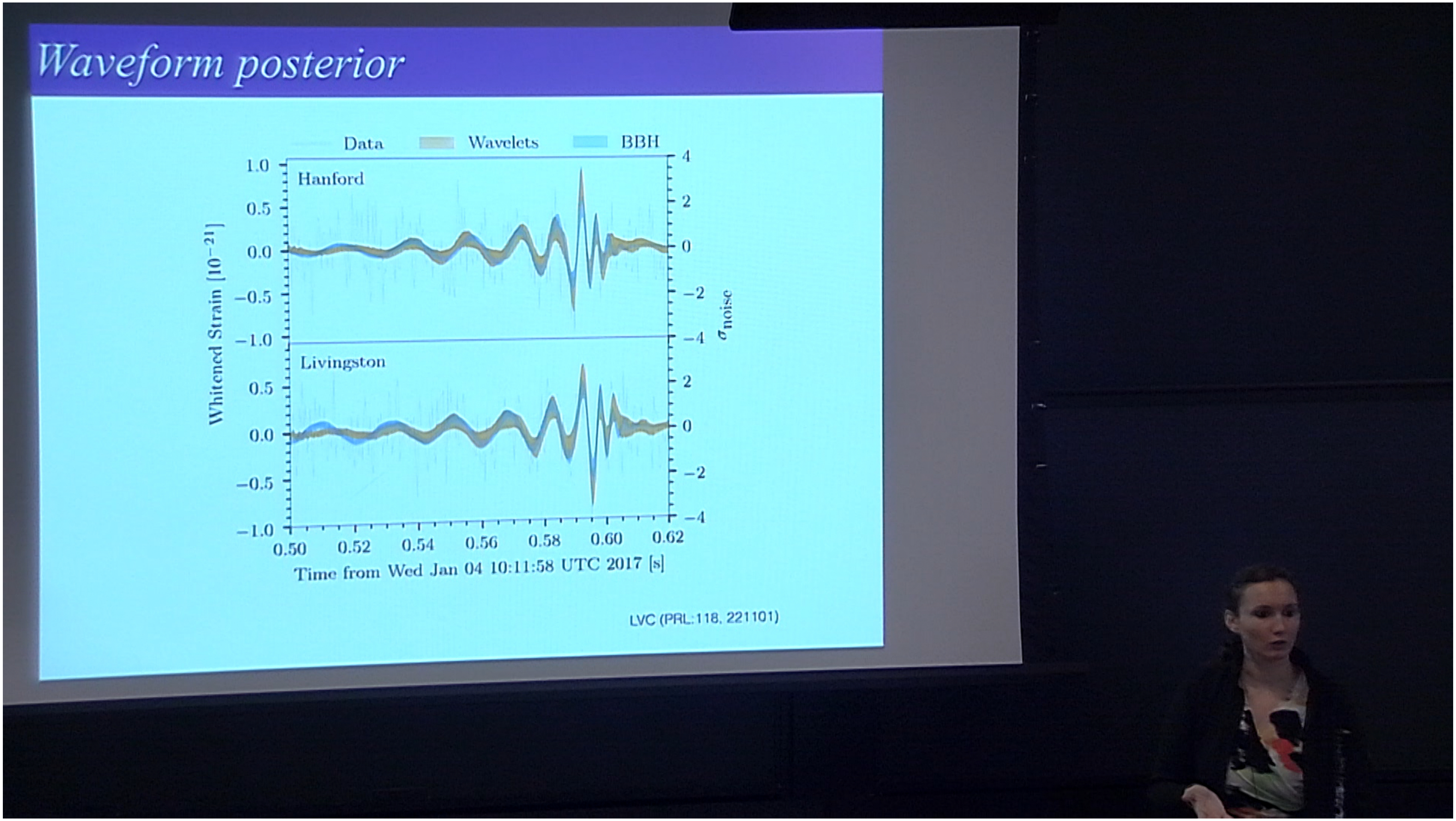


LVC/Meg Millhouse

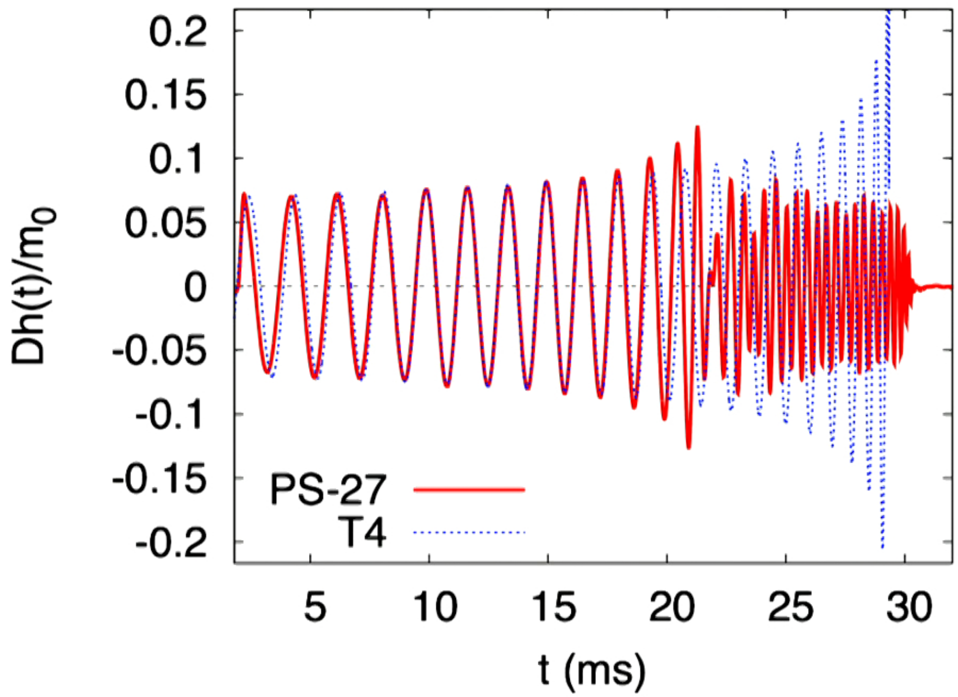
Waveform posterior



LVC (PRL:118, 221101)

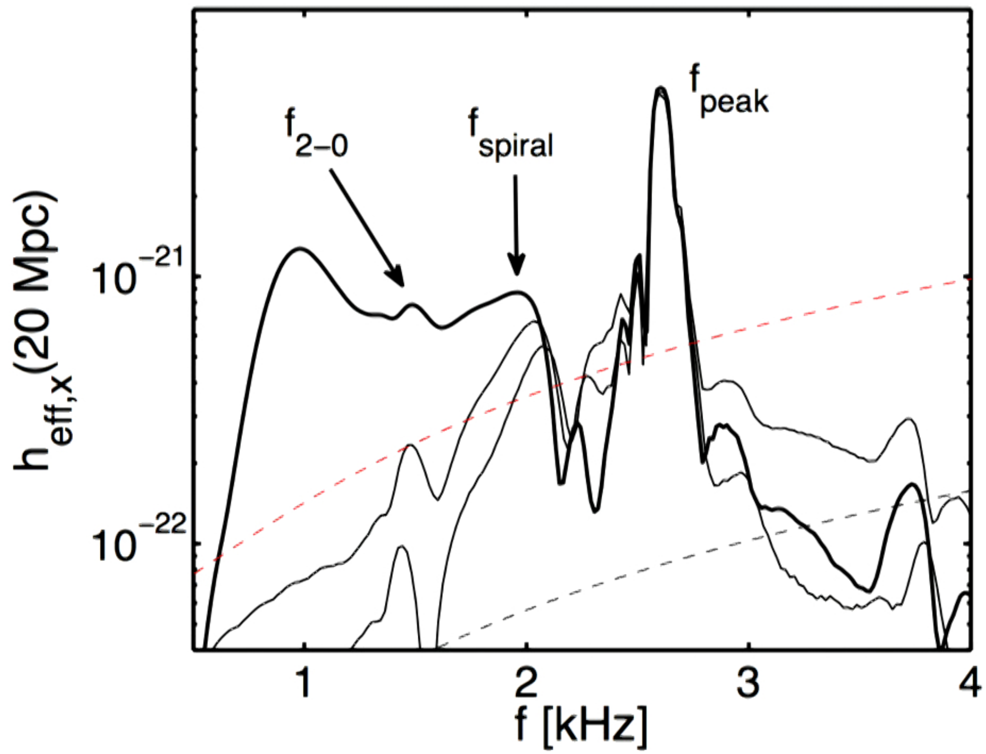

Waveform posterior
Data
Wavelets
BBH
Hanford
Livingston
Whitened Strain [10^−21]
σ_noise
Time from Wed Jan 04 10:11:58 UTC 2017 [s]
LVC (PRL:118, 221101)

Neutron star binary



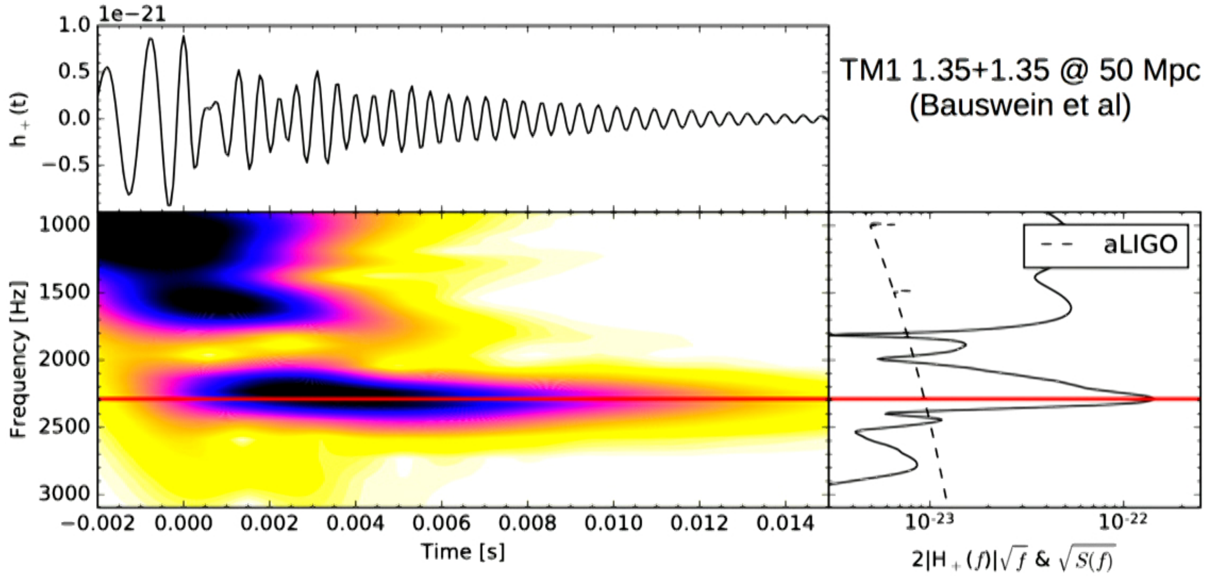
Hotokezaka+ (arxiv:1603.01286)
Hotokezaka+ (arxiv:1105.4370)

Spectrum



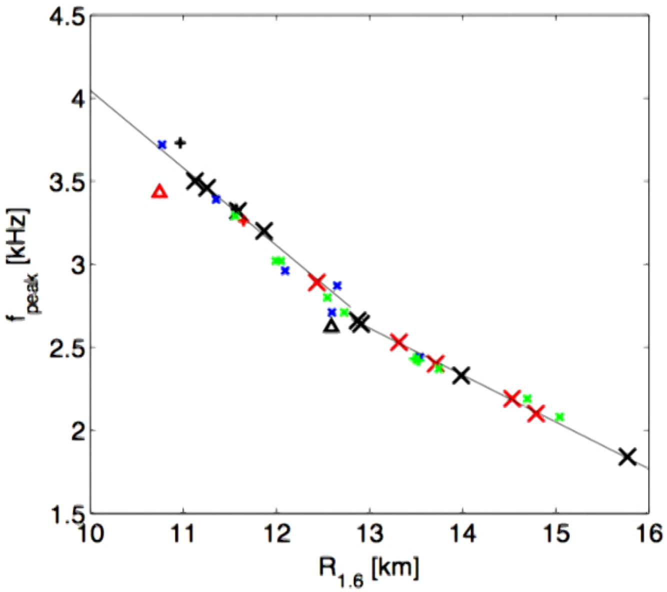
Bauswein+ (arxiv:1508.05493)

Post-Merger signal



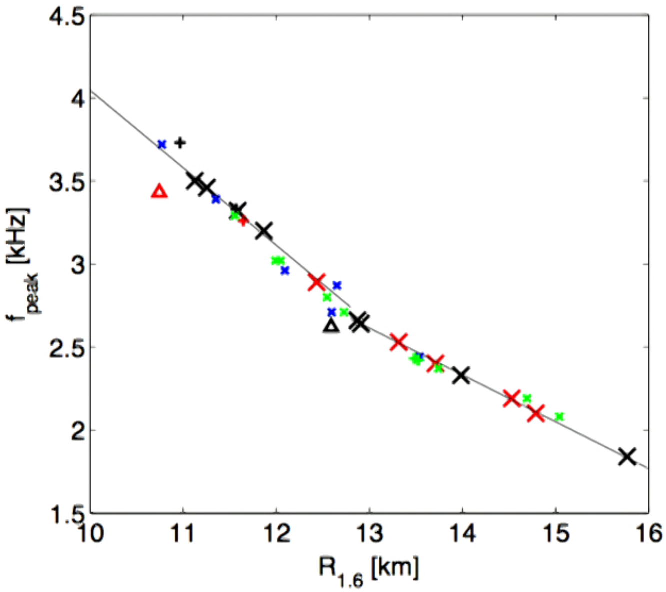
Clark+ (arxiv:1509.08522)
Bauswein+ (arxiv:1508.05493)

Peak frequencies

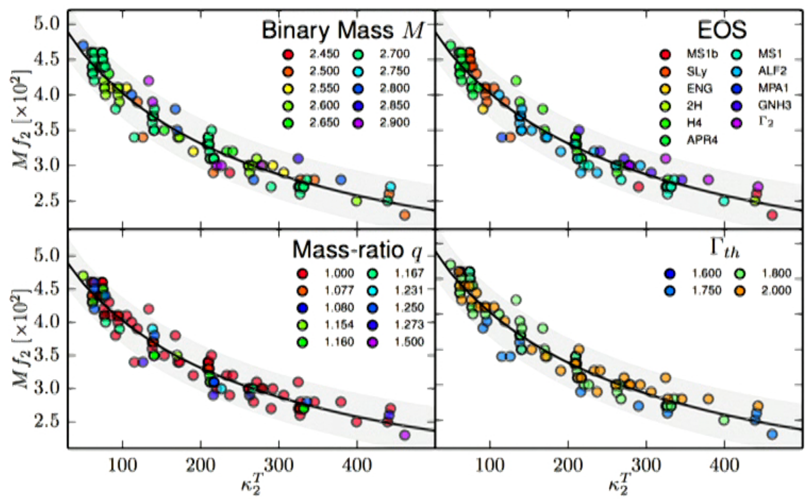


Bauswein+ (arxiv:1204.1888)

Peak frequencies

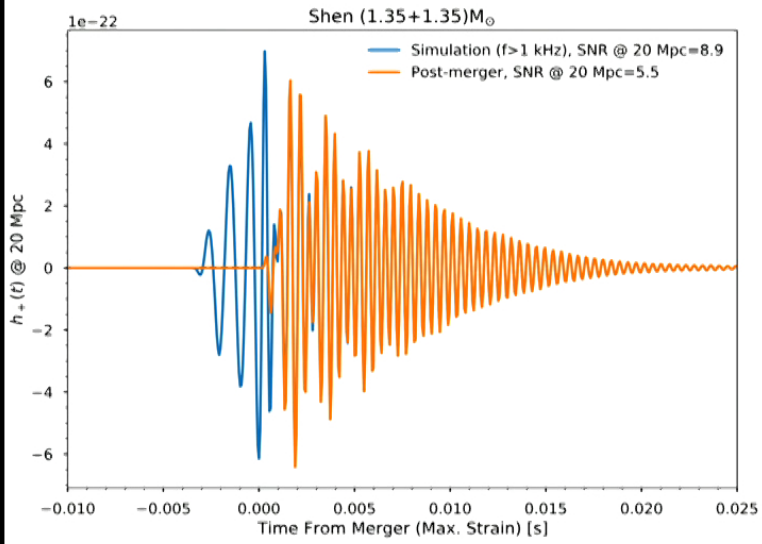


Bauswein+ (arxiv:1204.1888)



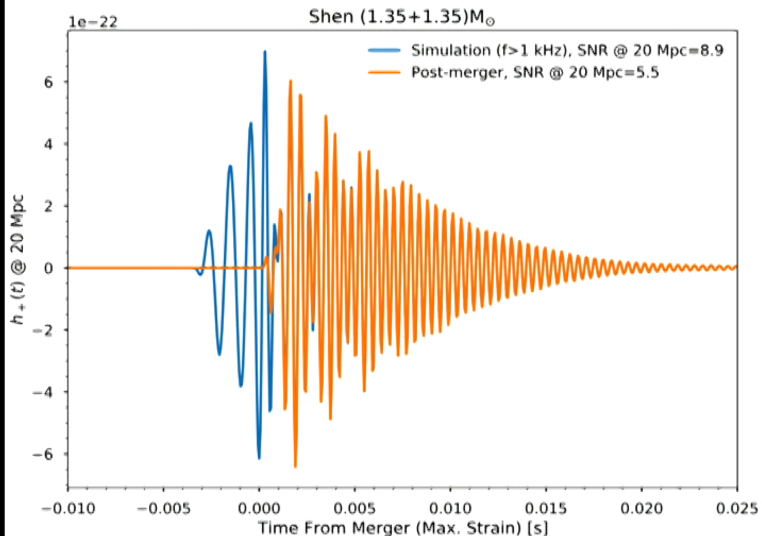
Bernuzzi+ (arxiv:1504.01764)

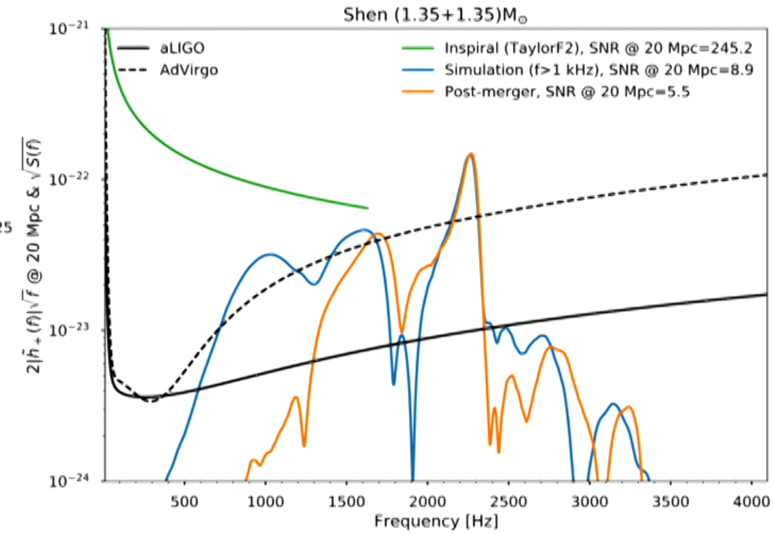
Enter BayesWave



Stergioulas+ (arxiv:1105.0368)
Bauswein+ (arxiv:1204.1888)

Enter BayesWave

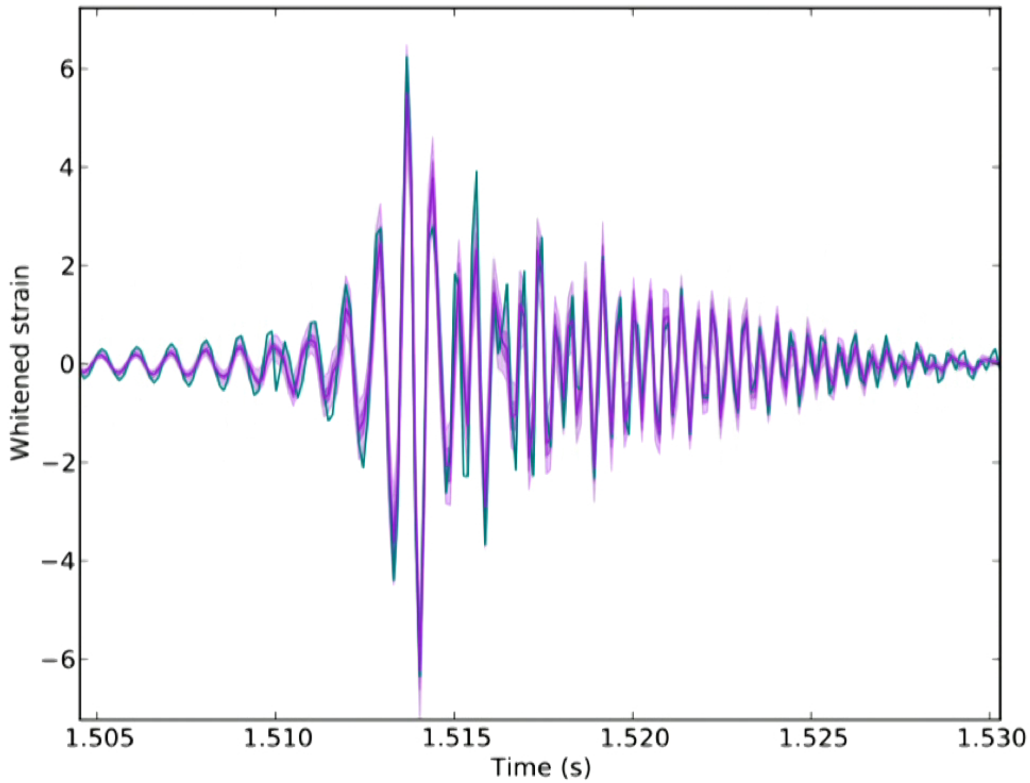




Stergioulas+ (arxiv:1105.0368)
Bauswein+ (arxiv:1204.1888)

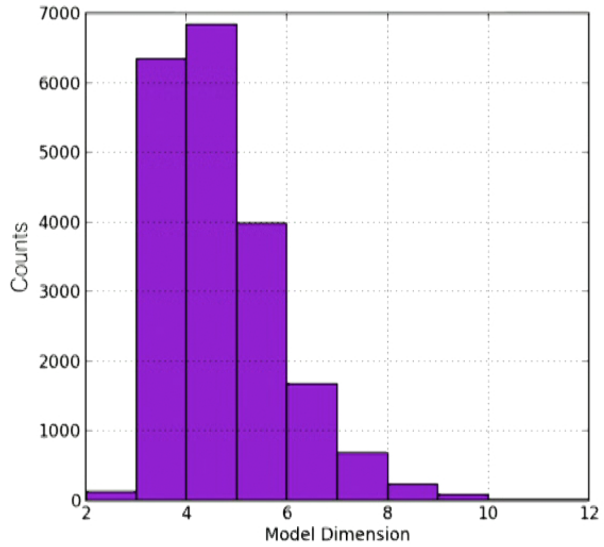
Reconstructed waveform

Waveform posterior with 50% and 90% credible intervals



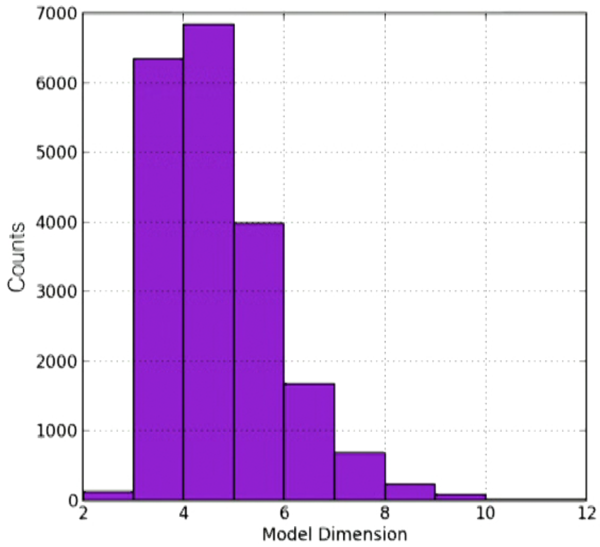
Wavelets

~15-20 parameters

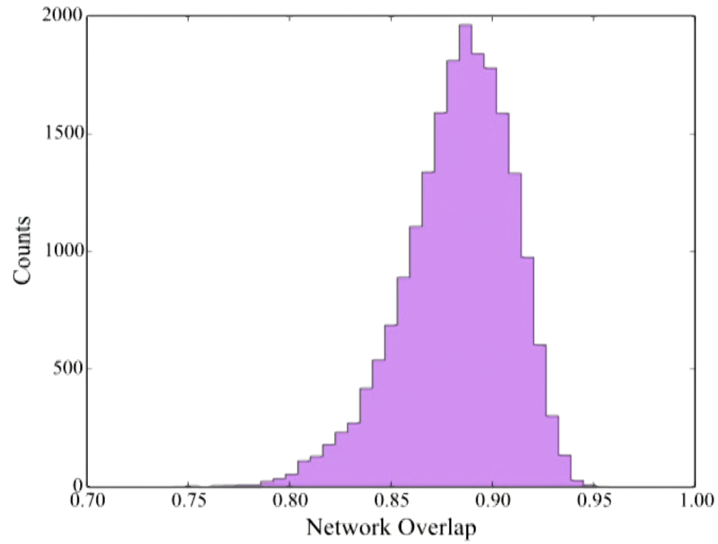


Wavelets

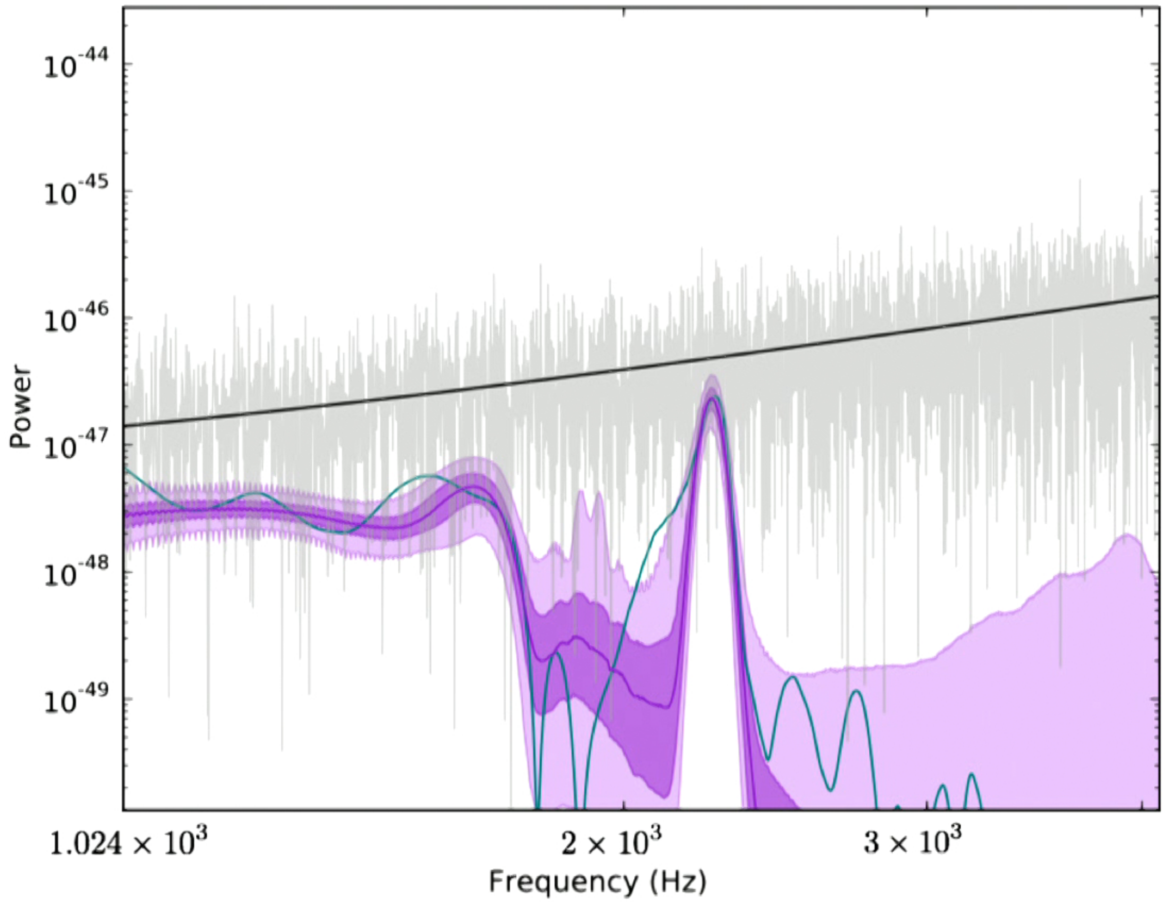
~15-20 parameters



$\mathcal{O} \sim < h_1 | h_2 >$

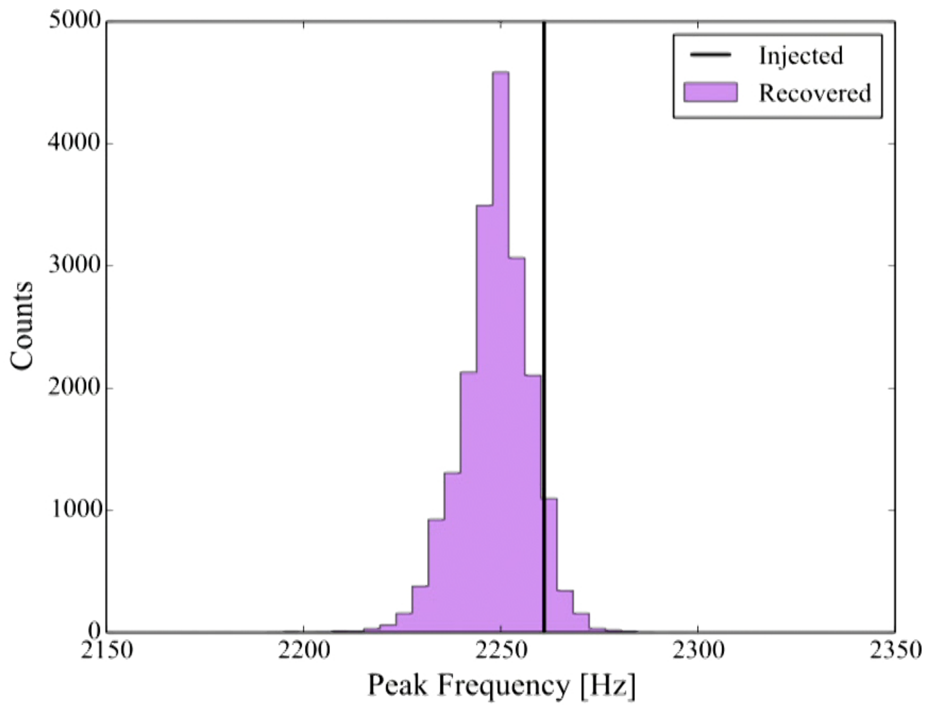


Reconstructed spectrum

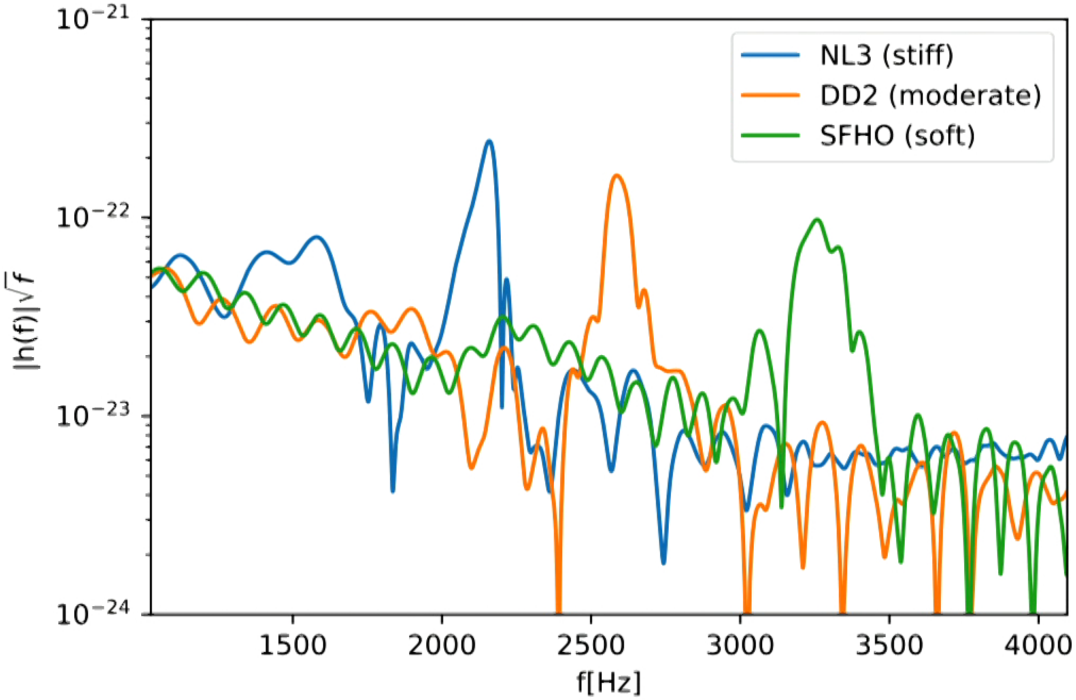


Peak frequency

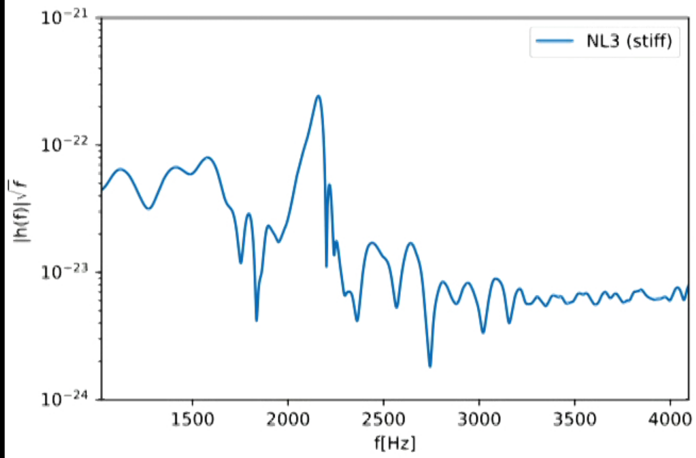
Extract peaks directly from the reconstructed signal

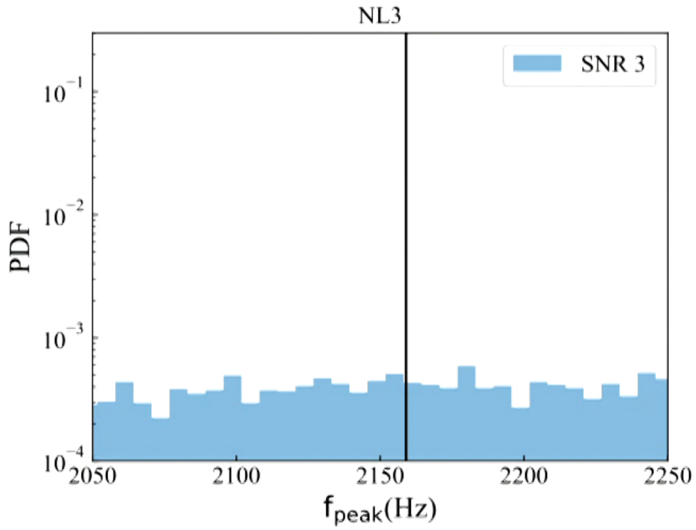


Systematic study

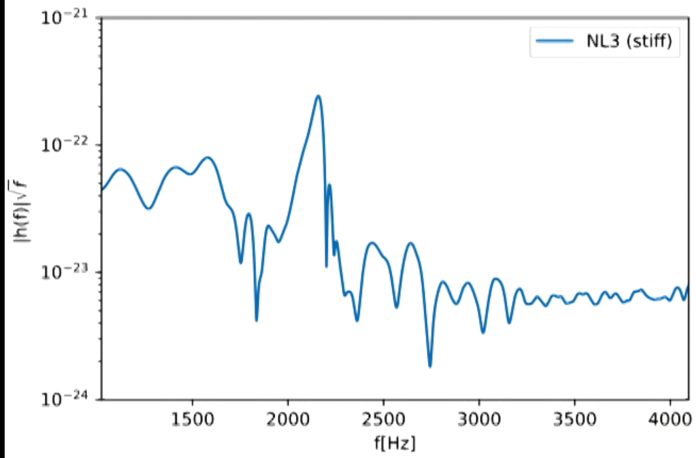


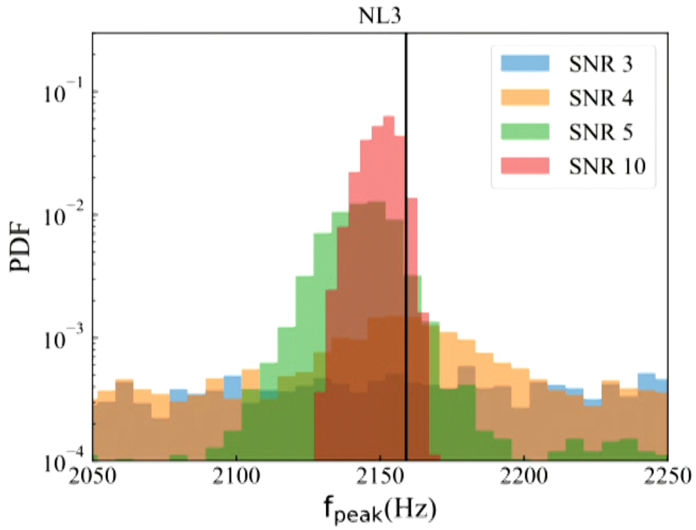
Peak frequency



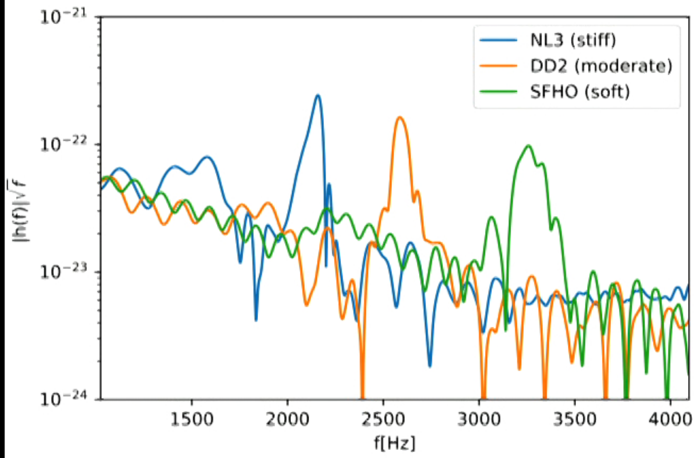


Peak frequency

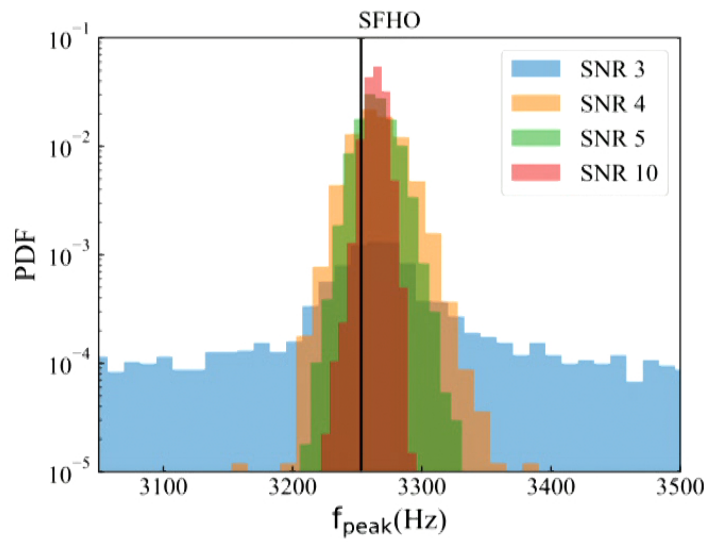




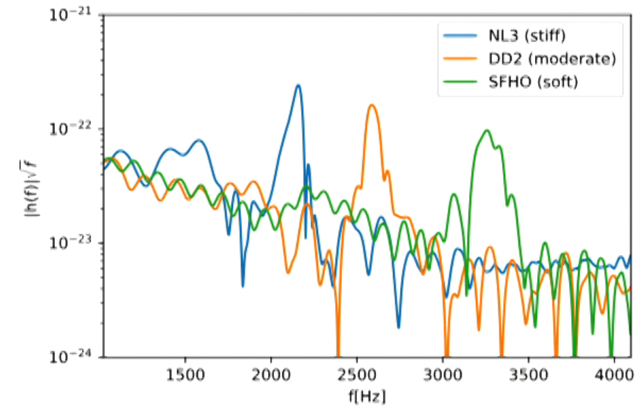
Peak frequency

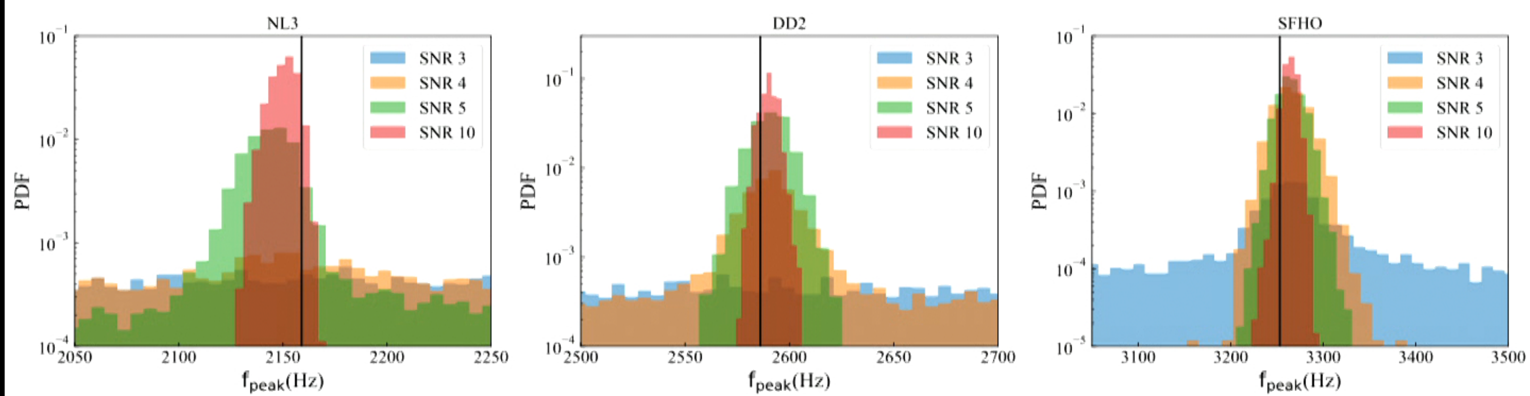


Small bias due to peak asymmetry



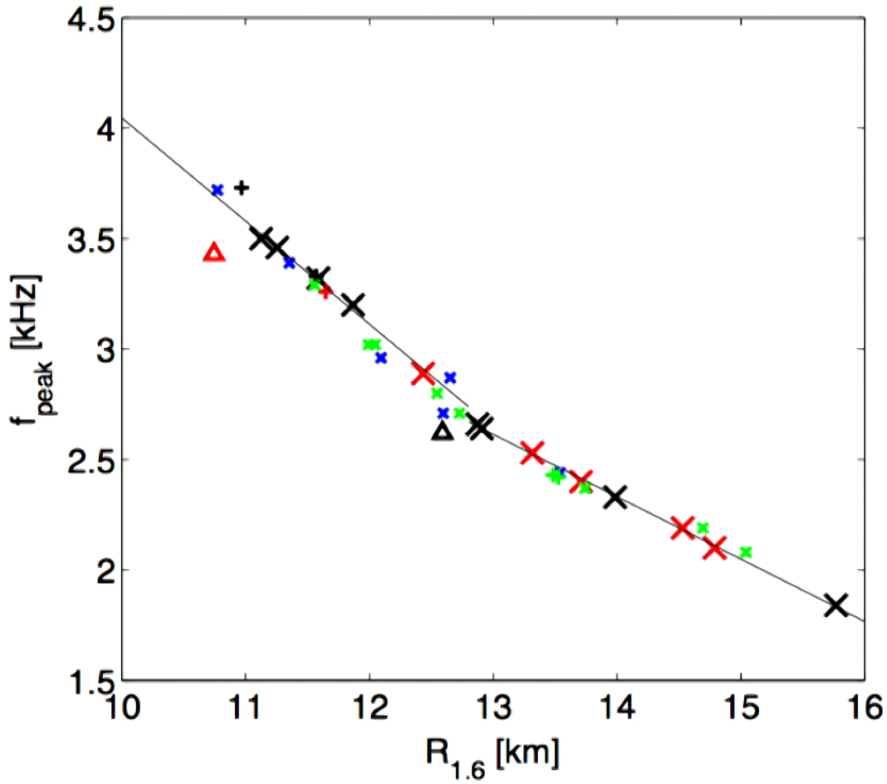
Peak frequency





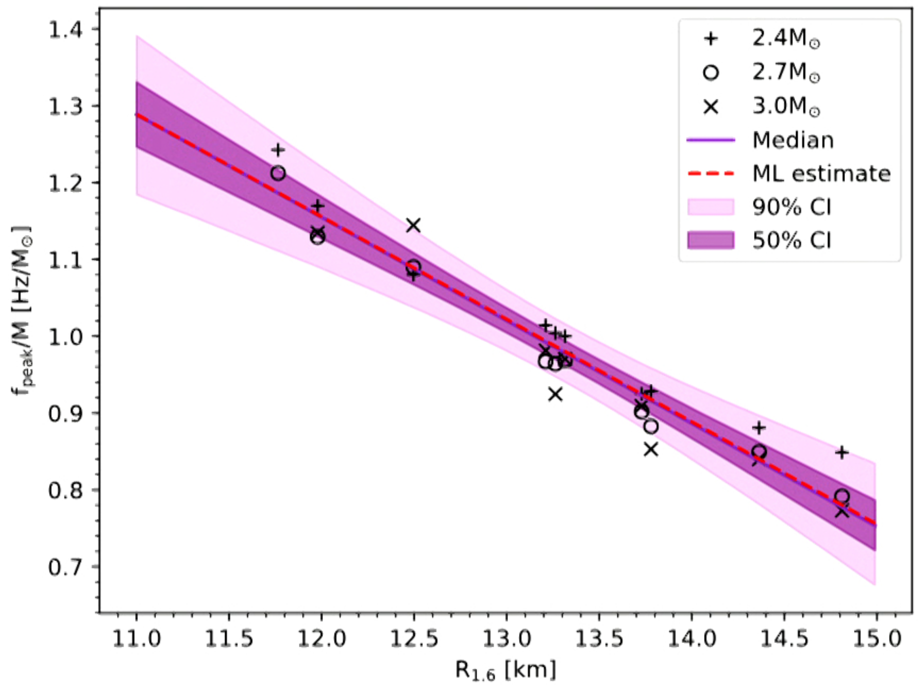
Easier to measure high frequencies

Universal relations



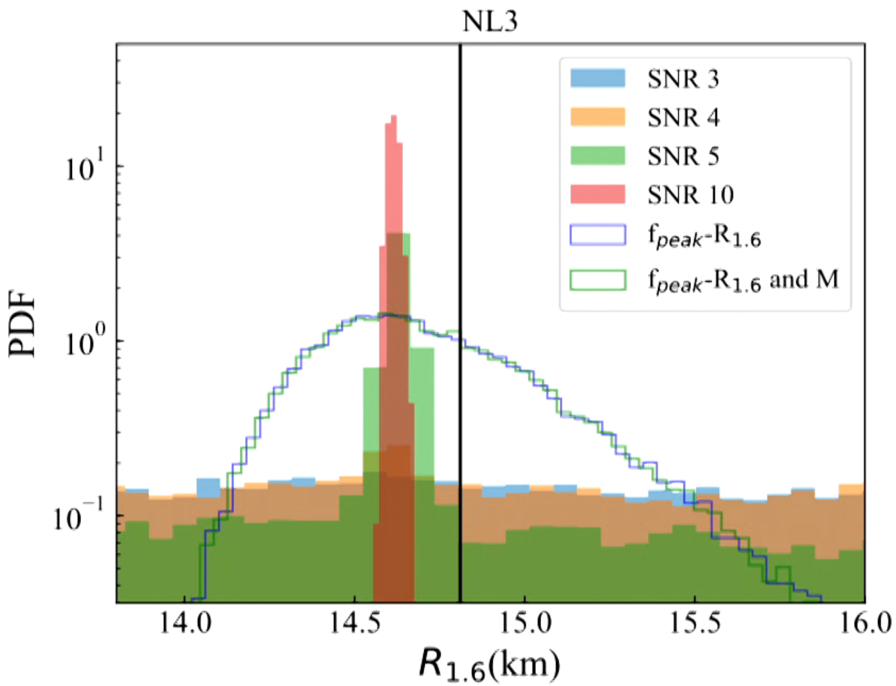
Bauswein+ (arxiv:1204.1888)

R16 uncertainty

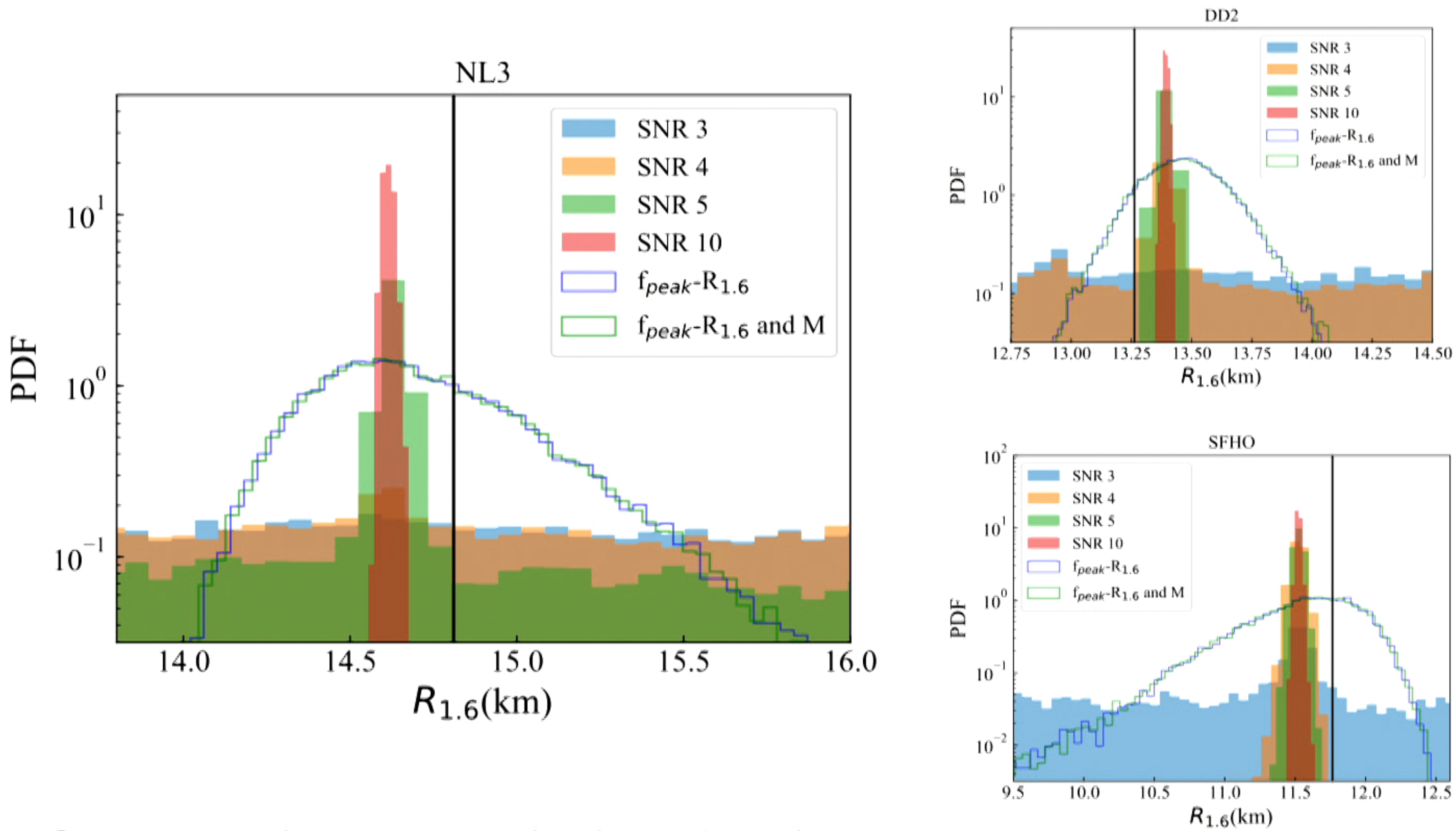


Bauswein+ (arxiv:1204.1888)
Bauswein+ (arxiv:1508.05493)

Marginalized R16



Marginalized R16

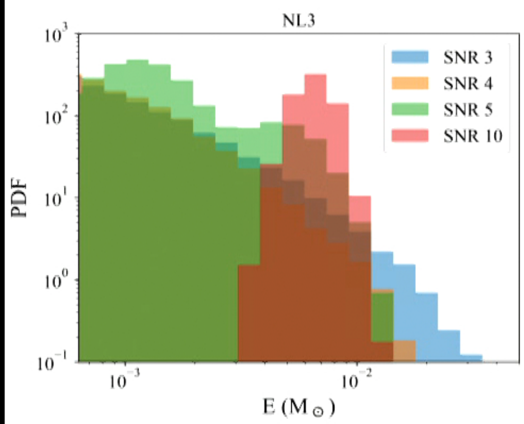


Systematic uncertainties dominate

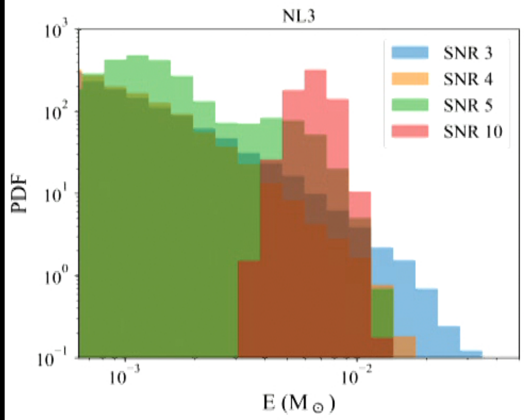
Energy emitted

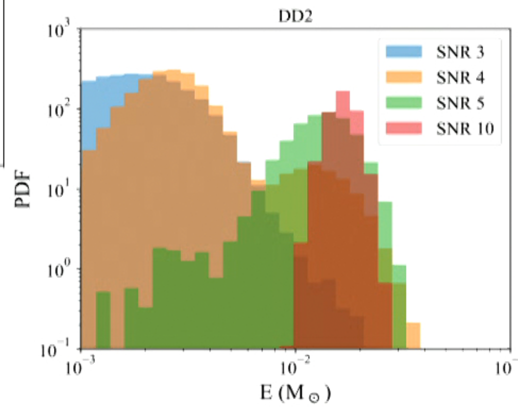
$$E_{GW} \sim \frac{D^2}{(1+\cos^2\iota)^2} \int_{f_{min}}^{f_{max}} df\, f^2 |\tilde{h}(f)|$$

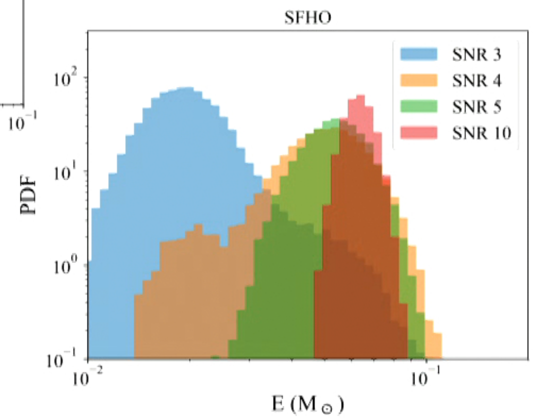
Energy emitted



Energy emitted

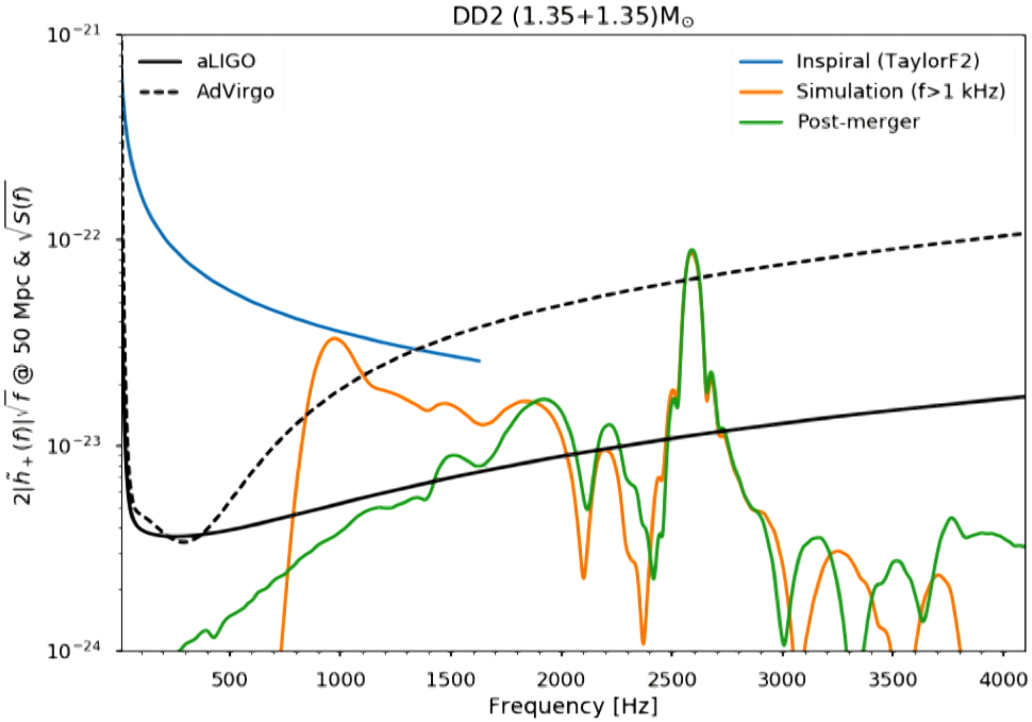






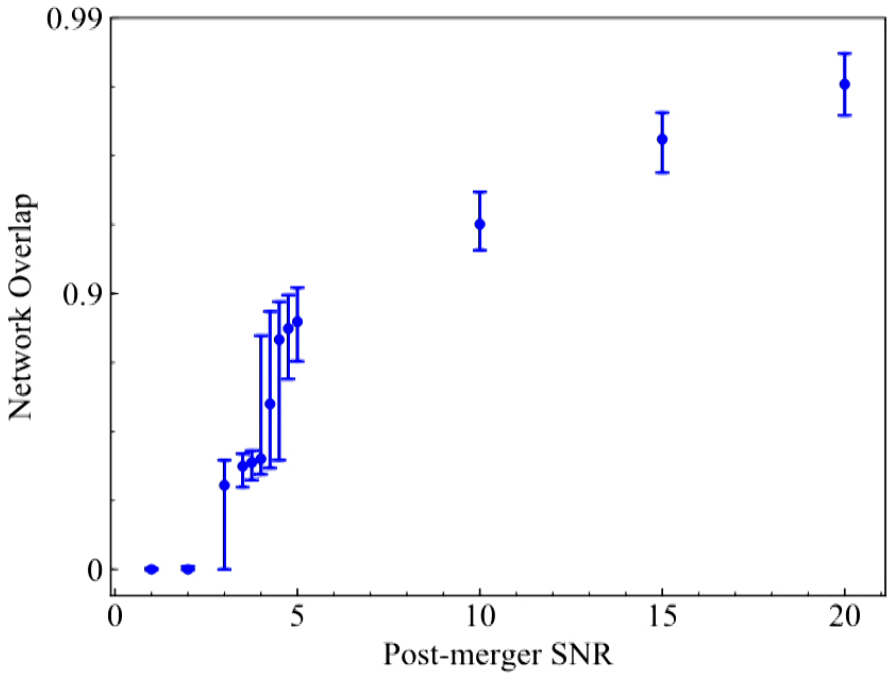
Measure the energy emitted and place upper limits

Population study



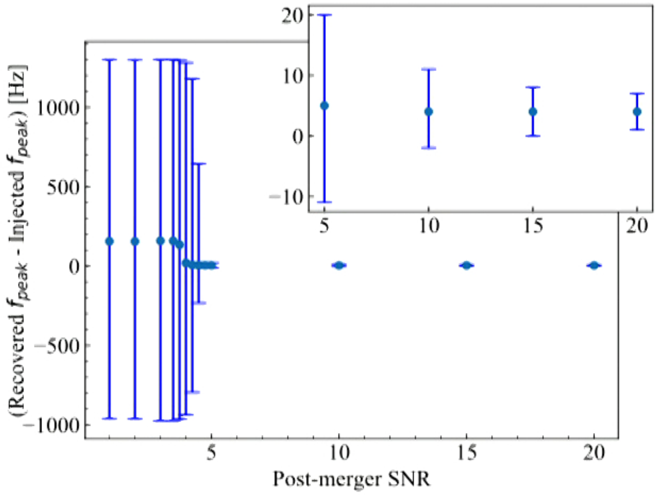
Bauswein+ (arxiv:1307.5191)

Reconstruction

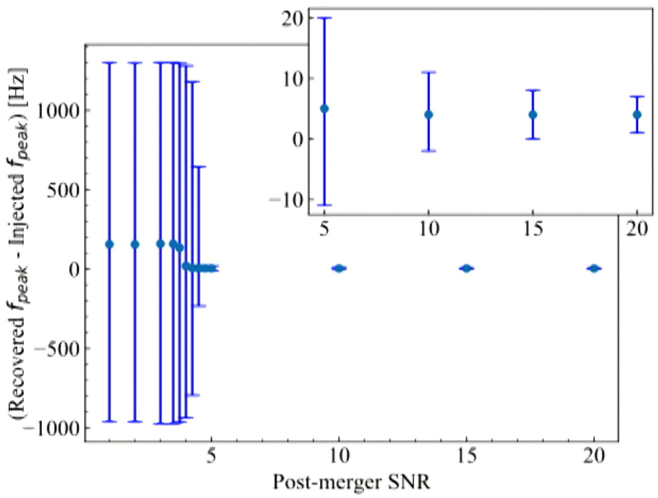


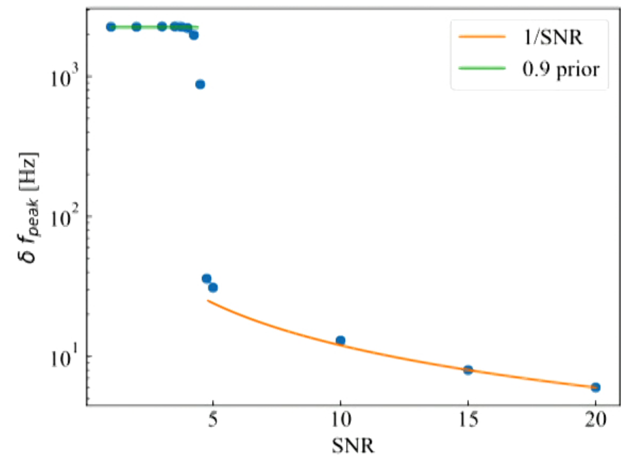
Overlaps ~80-90%

Sensitivity: peak frequency

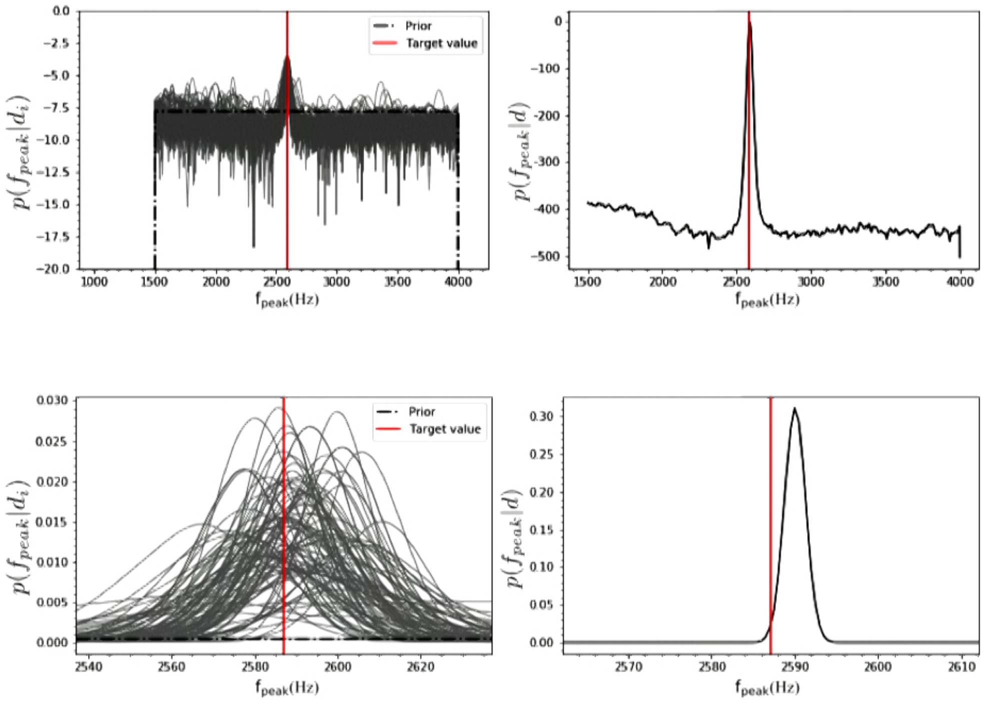


Sensitivity: peak frequency



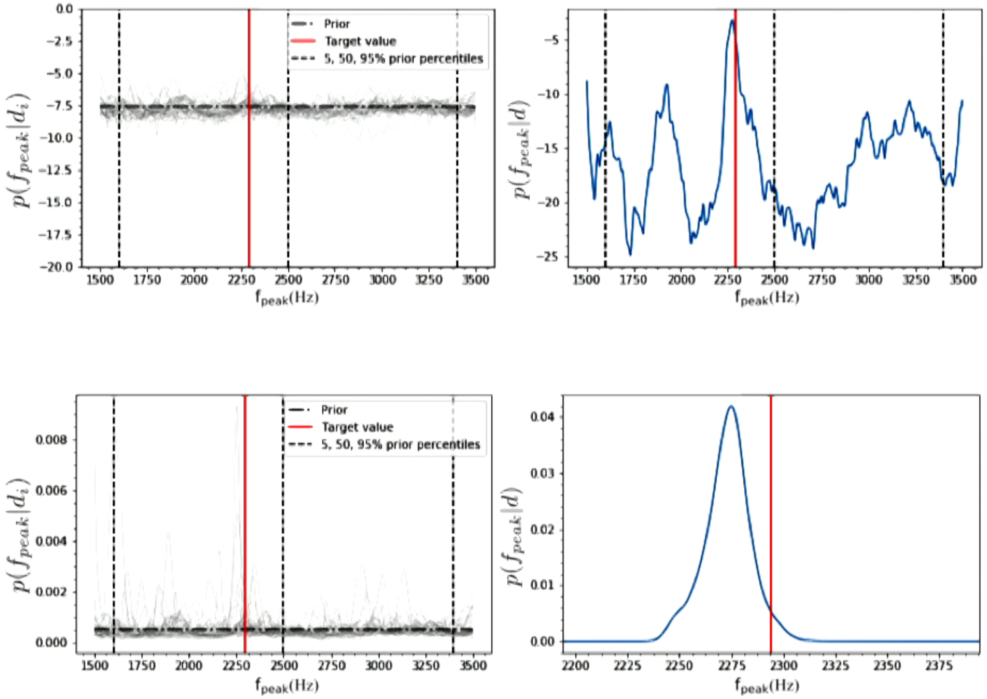


Loud signals



100 SNR 5 signals
~ 1 SNR 50 signal

Subthreshold signals



500 uniformly distributed signals in 5-200Mpc

Thank you!