Fast parameter estimation with relative binning

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Outline

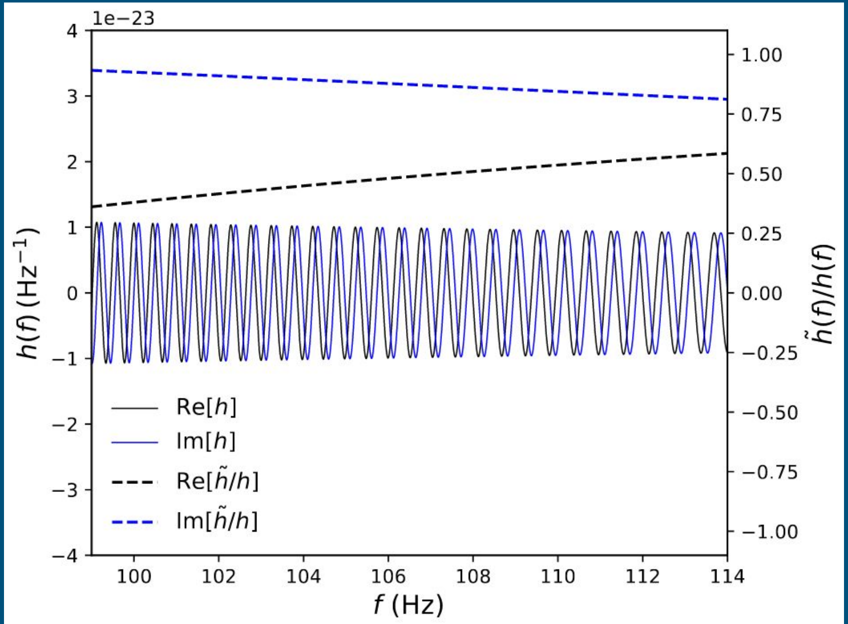
- Background info -- what is relative binning and why do we care?
- Details of our implementation and analysis
- Results from the paper [link]
- Possible prospects for 3G detectors

Background

Long duration signals (e.g. BNS) are computationally expensive to analyze using standard methods -- uniform sampling means ~500k frequencies (from 20 Hz) in each likelihood evaluation

If near-peak likelihood parameters are known, can use *ratio* of waveforms in this neighborhood, which is slowly varying function of frequency (needs fewer samples)

Bin frequencies are chosen to capture changes in GW phase (non-uniform)



Zackay et al. (2018)

Analysis details

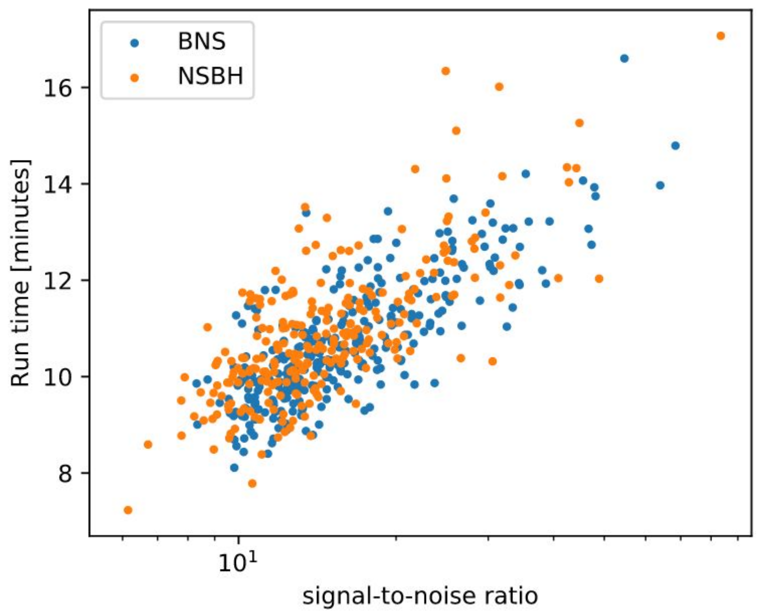
- Demonstrated relative binning is a fast and accurate method to produce parameter estimates for prioritizing EM follow-up observations
    - low-latency search pipeline best-fit waveform is “close enough” to seed analysis
- Incorporated relative likelihood model into PyCBC inference
- Developed for coherent detector network allowing measurement of sky location
- Applied method to populations of BNS and NSBH signals in a 3-detector HLV network; also reproduced analysis of GW170817

Speed

All signals were recovered in <20 minutes on 32 cores (mean runtime was 10.8 minutes)

No significant difference in runtime between populations

We did see slight SNR dependence, possibly due to nested sampling algorithm (though this hasn't yet been investigated)

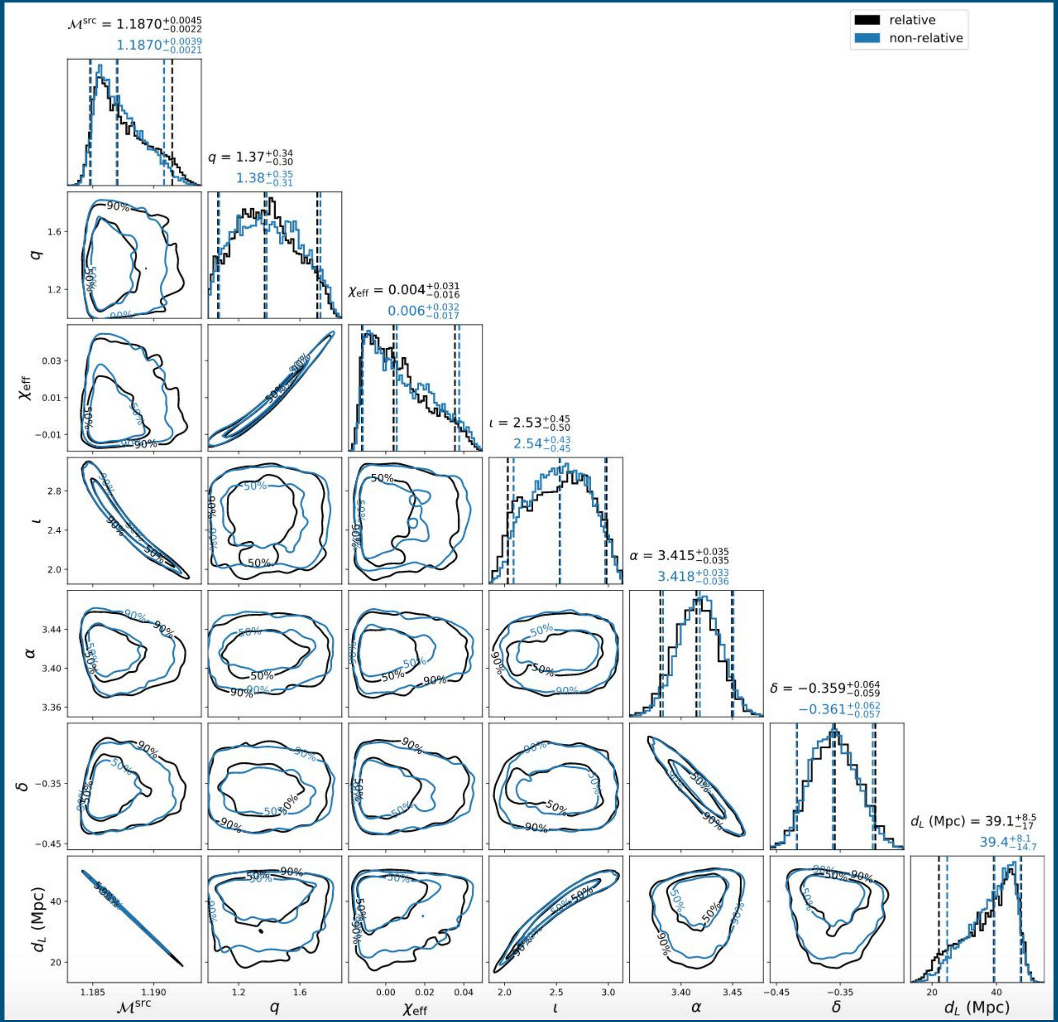


Accuracy (pt. 1)

We analyzed GW170817 using relative and non-relative likelihoods for comparison

Tried to mimic an immediate post-detection analysis: measured sky location, but not tides

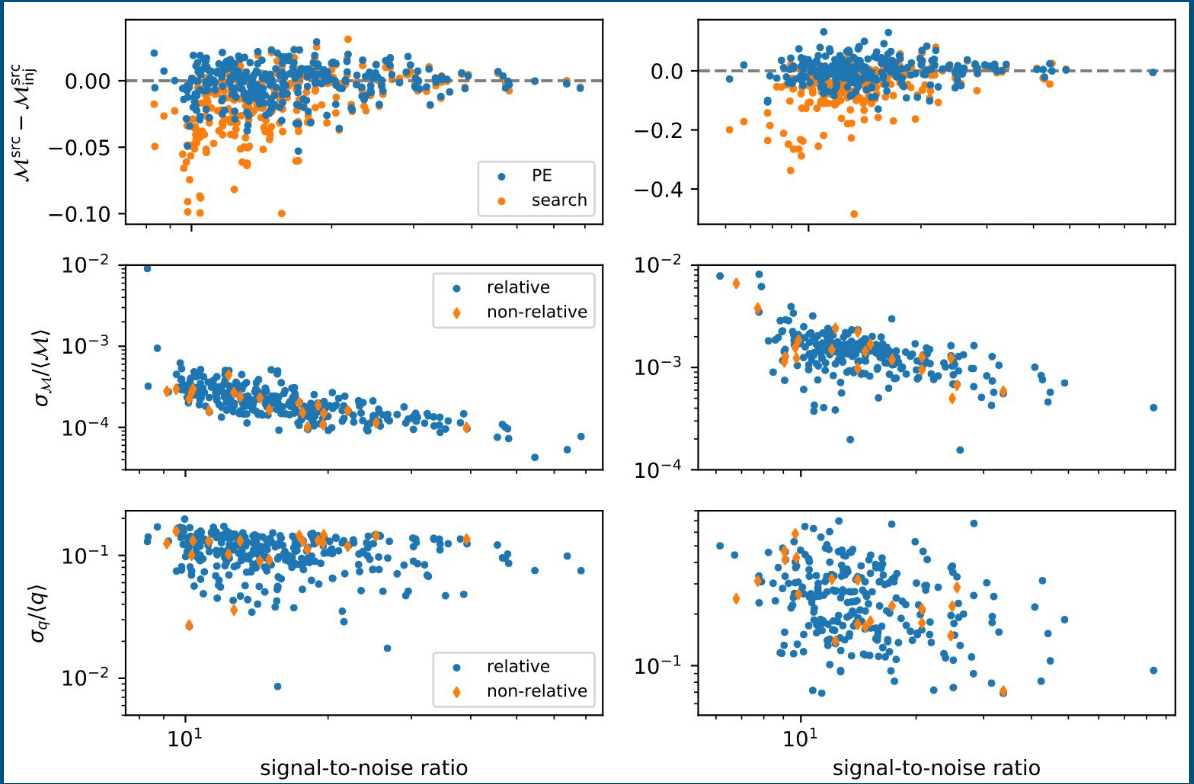
Relative analysis finished in 20 minutes, vs 3 hours for non-relative, and we found negligible differences in results between the two



Accuracy (pt. 2)

Source-frame chirp mass nominal (median) posterior values showed improved accuracy over best-fit template value, i.e. these are better estimates to give EM follow-up campaigns

Fractional uncertainties in chirp mass and mass ratio are comparable between relative and non-relative analyses



Preliminary prospects for 3G

- Signals in 3G detectors can be *even longer* because of low frequency sensitivity; standard PE methods become computationally intractable
  - 4k second duration from 7 Hz, roughly 8 *million* frequency samples per waveform
- Relative binning seems to require only ~12k frequency samples; CE trial run of SNR 50 BNS signal (f_low=7 Hz, aligned spins, with tides) completed in ~45 minutes on 32 cores
- More testing needed to confirm binning for full range of parameter space, when using best-fit template params, etc.

Thanks!