# SPIIR online CBC postcoherent search pipeline

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## Motivation

- Low-latency detection of gravitational waves from compact binary coalescence is necessary to facilitate electromagnetic follow-up of these events, allowing multi-messenger astronomy.
- As the lower frequency cutoff of the detectors improve, the signal length of inspiral events increases rapidly; this can lead to significant increase in the computational cost or latency of FFT-based matched filtering.
- The SPIIR pipeline provides a computationally-efficient time-domain (and therefore low-latency) filtering.
- Coherent search is used to provide low-latency localization.

## Waveform approximation

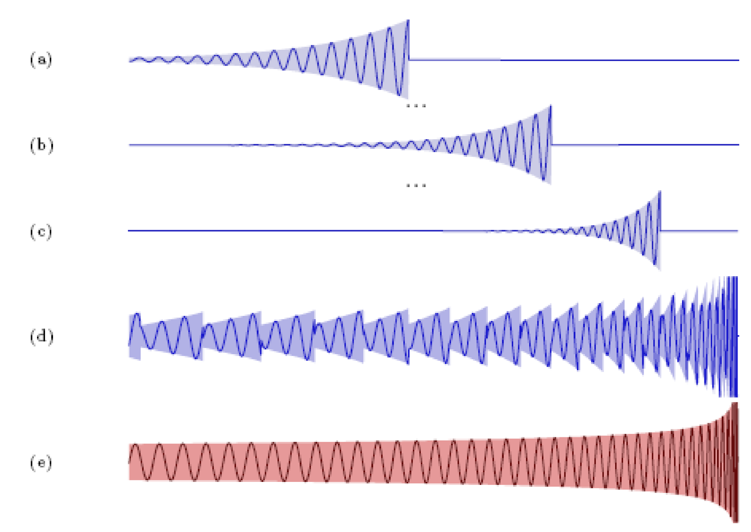



Figure from Hooper [3]

Starting from the template of a compact binary inspiral waveform (e), an approximation (d) is formed from the sum of damped sinusoids (a)$\cdots$(b)$\cdots$(c). The approximation is obtained through a sequence of Taylor expansions of the phase of the waveform, where the time steps are determined by the error of the approximation and the second derivative of the phase at that time [4, 6, 7]. Further work has gone into optimizing the approximation obtained to maximize overlap with the template waveform [8].

## SPIIR filtering

Convolution of the signal $w_k$ with the damped sinusoid can be achieved through the simplest IIR filter, parameterized by $(a_1, b_0)$:

$$y_k = a_1 y_{k-1} + w_k b_0$$
$$= b_0 \sum_{j=-\infty}^{k} w_j a_1^{k-j}$$

So the convolution with the waveform can be approximated by the sum of many IIR filters; this problem is particularly well-suited to GPU optimization [5]. Further computational efficiency has also been achieved using multi-rate sampling [2].

## Post-coherent search

When a sufficiently strong response is found in one detector, an all-sky coherent search is triggered. For each sky direction the coherent SNR and, with three or more detectors, the null stream are computed. The figure shows the probability (proportional to exp of the coherent SNR squared) the injected signal arose from the sky direction marked with the blue star, the maximal probability is given by the white star.

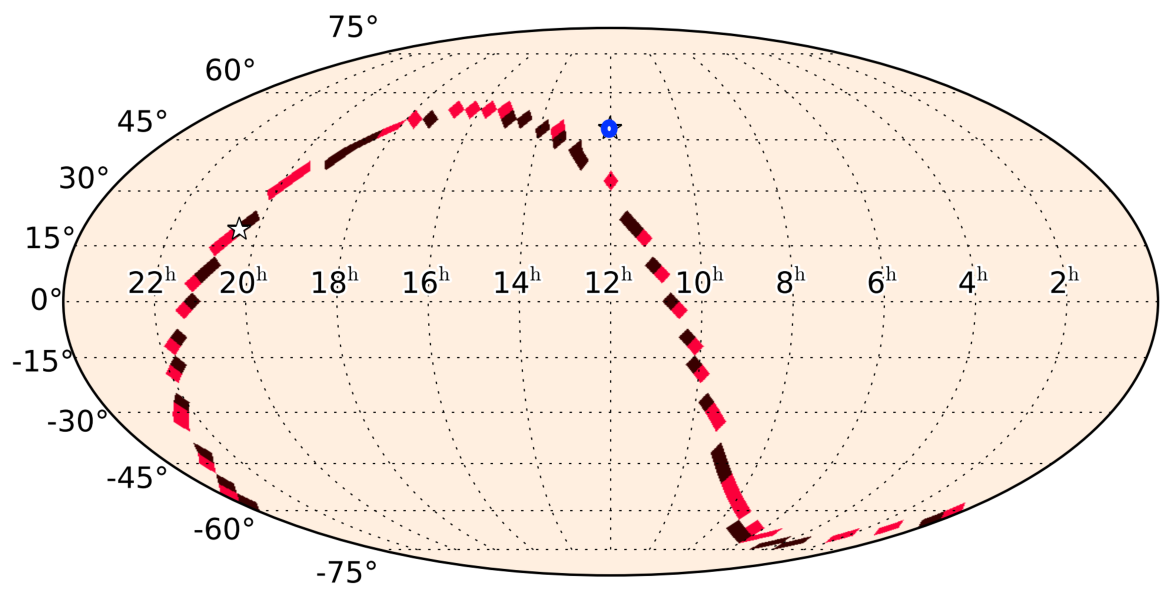
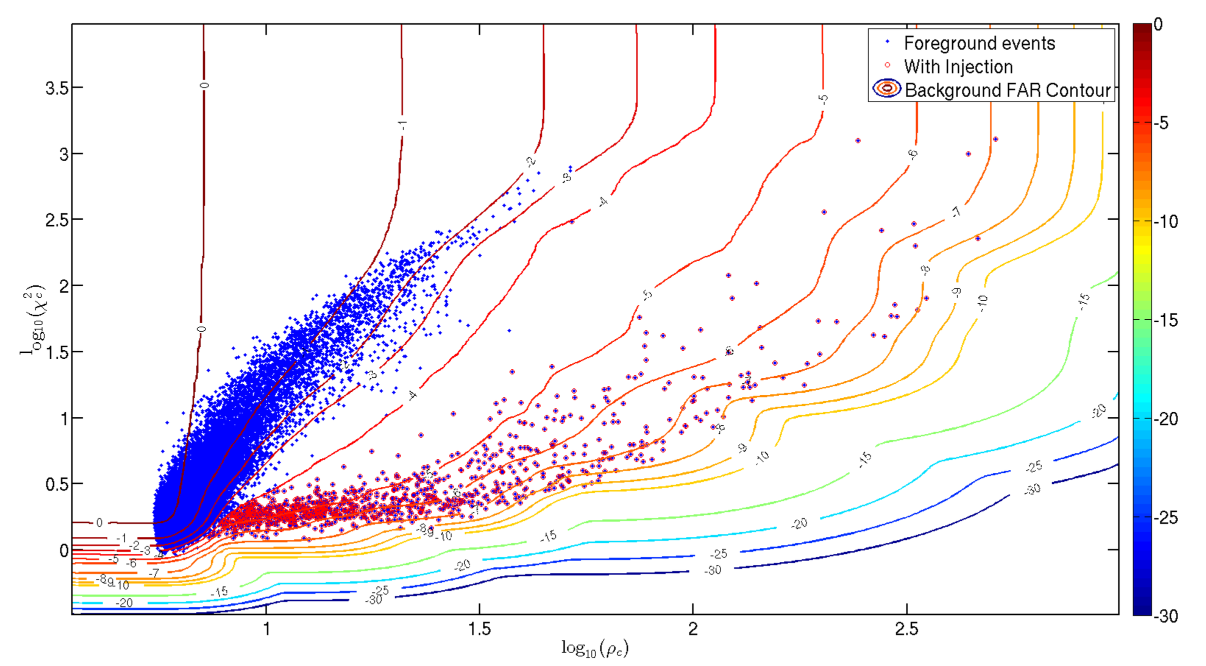



Figure from Chu [1]

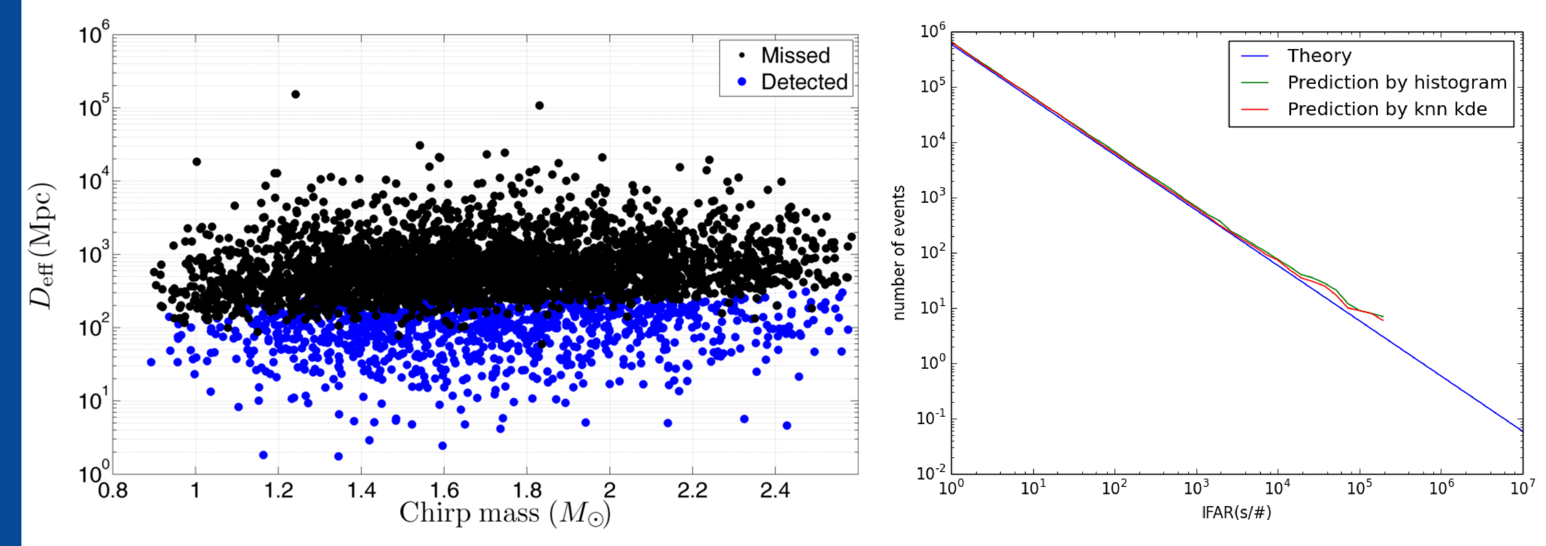
## FAR estimation

The false alarm rate is estimated by running the pipeline on simulated background noise, obtained through time shifting one detector relative to the other. A histogram of SNR and $\chi^2$ for background triggers is formed and kernel density estimation is used to generate a probability density of background triggers, the contours of the associated FAR are plotted below. Triggers associated with injections can be clearly distinguished from those without.




## Mock Data Challenge

The efficacy of the pipeline is tested using on the order of one million seconds worth of detector noise combined with injections. The missed and found injections are plotted with respect to their chirp mass and effective distance, and injections at an effective distance of 100Mpc can be detected as expected.
With simulated background noise, the number of triggers with an estimated FAR above a certain threshold should be proportional to the threshold; adjusting the threshold and counting the number of events provides a consistency check for the FAR estimation; as can be seen, our method provides a good estimation of the FAR.




## Ongoing Work

- Further optimization of the IIR filter generation.
- Extracting more localization information from the skymaps.
- Tuning pipeline for the three detector configuration.
- Further improvement of the FAR estimation.
- Additional glitch veto mechanisms.
- Reduction of pipeline latency from $\sim 20$ seconds to $< 10$ seconds.

## Bibliography

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