Reducing Early Warning Retractions to Facilitate Multi-Messenger Astronomy

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Why is Early Warning Detection Important?

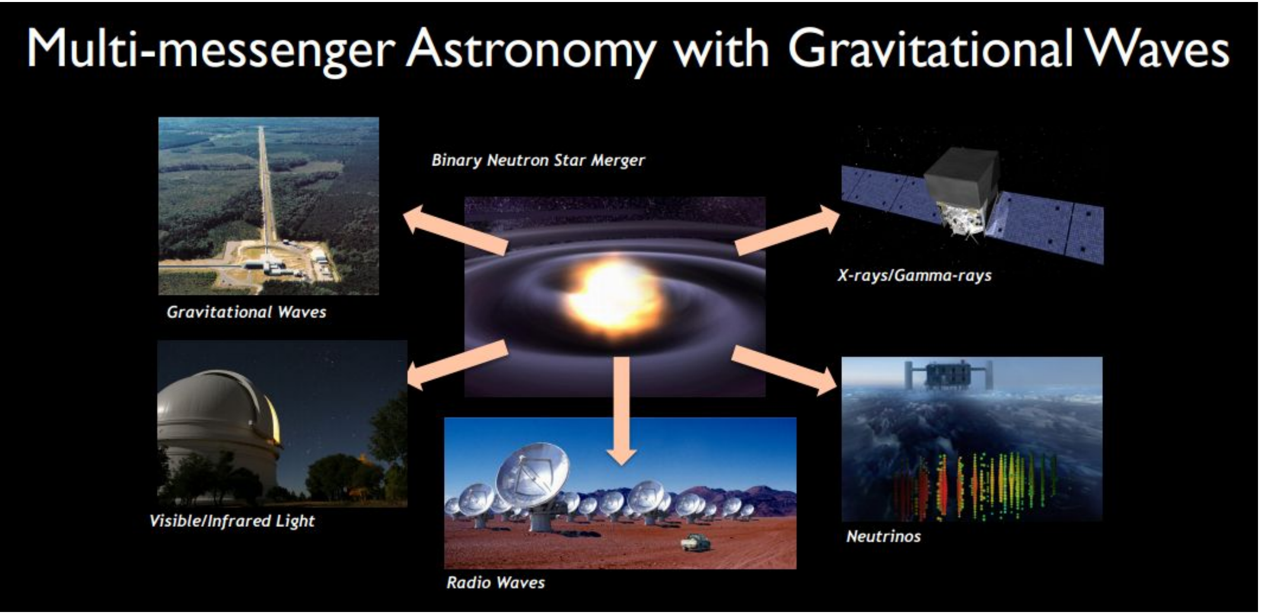
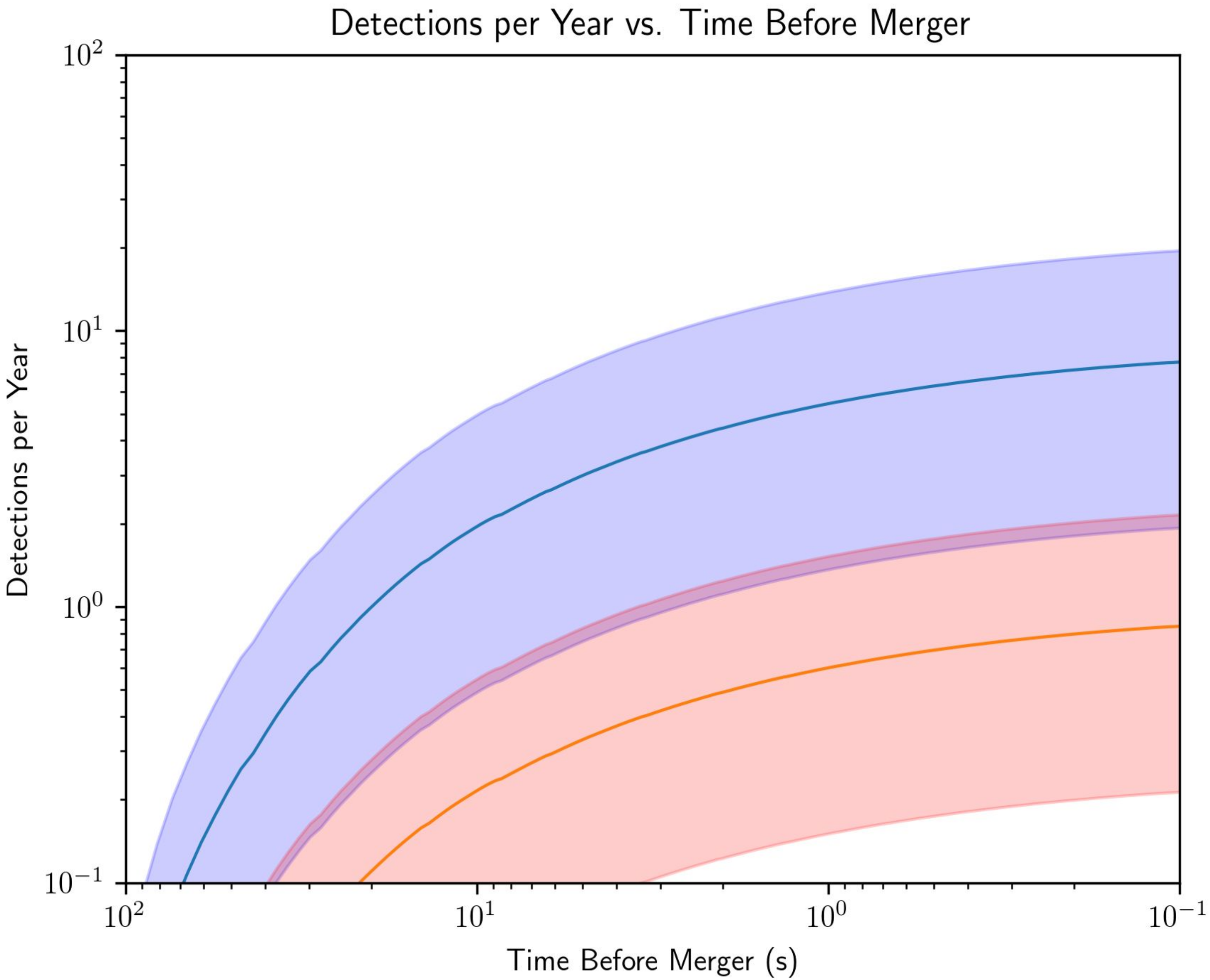


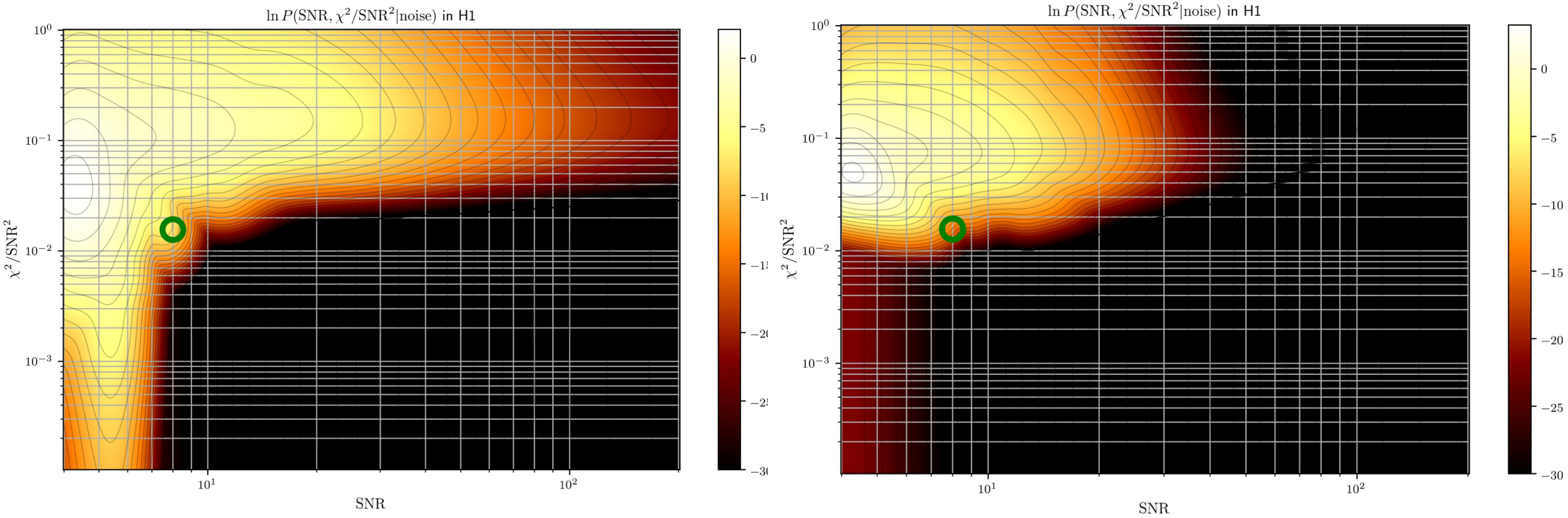
Image credit: Laura Cadonati, Georgia Tech LIGO Scientific Collaboration

- GW 170817: ~40 minutes between GW arrival to Earth and distribution of alert and ~4.5 hours before distribution of sky localization
- Early warning detection is important because we can learn more about binary neutron star mergers through prompt emission



- We could detect approximately 8-9 events per year and 1 detection per year that is ~10-20 seconds early
- We could also detect 1 multi-messenger astronomy event in O4

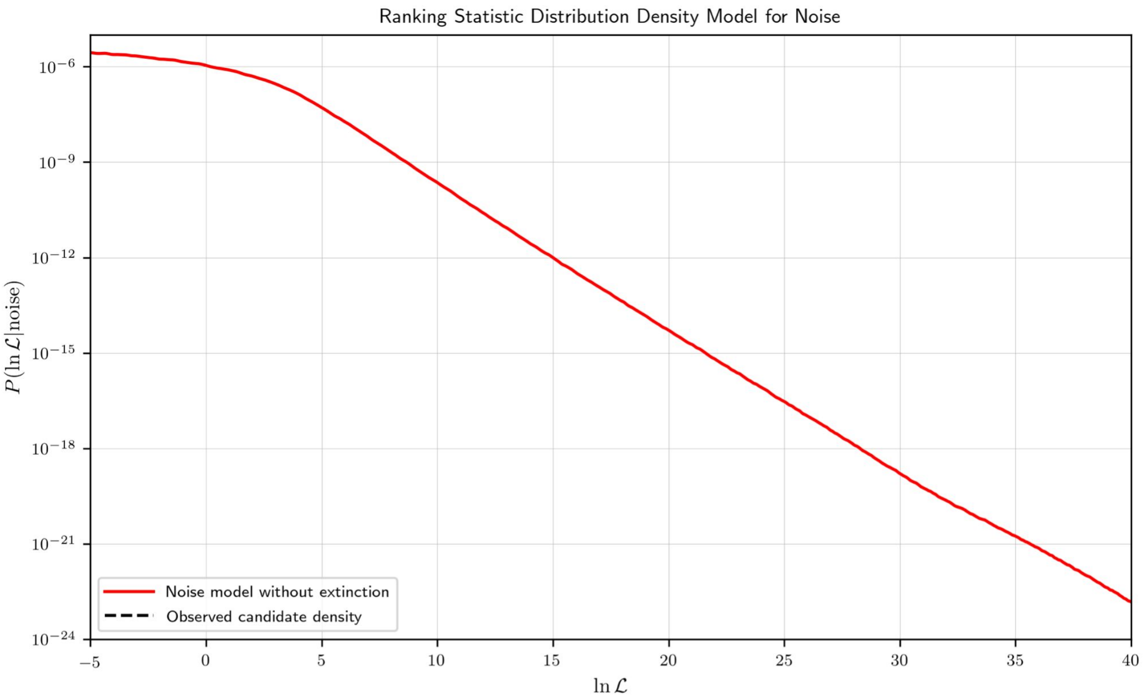
Background Plots



Comparison of background for a run with an upper frequency bound of 29 Hz and 1024 Hz. These plots have SNR on the x-axis and chisq on the y-axis, where the green dot is located at SNR=8 and chisq=1.

From Likelihood Ratio to False Alarm Rate

- From the background plots produced, we obtain the likelihood ratios of the candidates which measures how likely the signal is due to a gravitational wave event and not noise
- The false alarm rate is the complementary cumulative distribution of the log likelihood ratio of the noise over time



What Am I Testing?

- Whitened and recolored a two week segment of LIGO O3a data to run through the GstLAL pipeline and analyze for different upper frequency bounds corresponding to different early warning times
    - Three different analyses for three different upper frequency cutoffs
- How does the false alarm rate change for a single analysis vs. three different analyses?

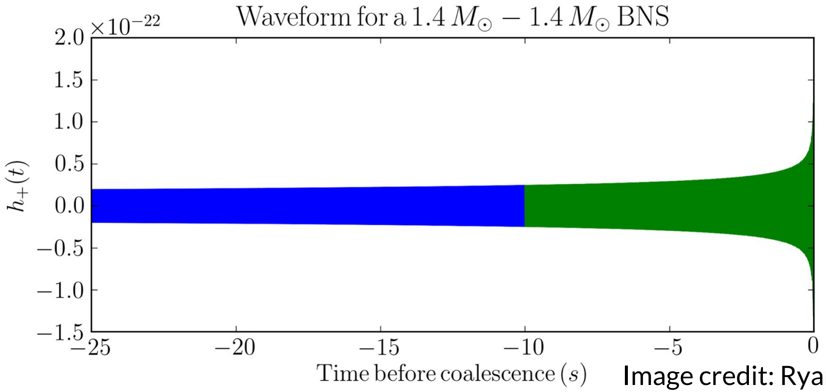
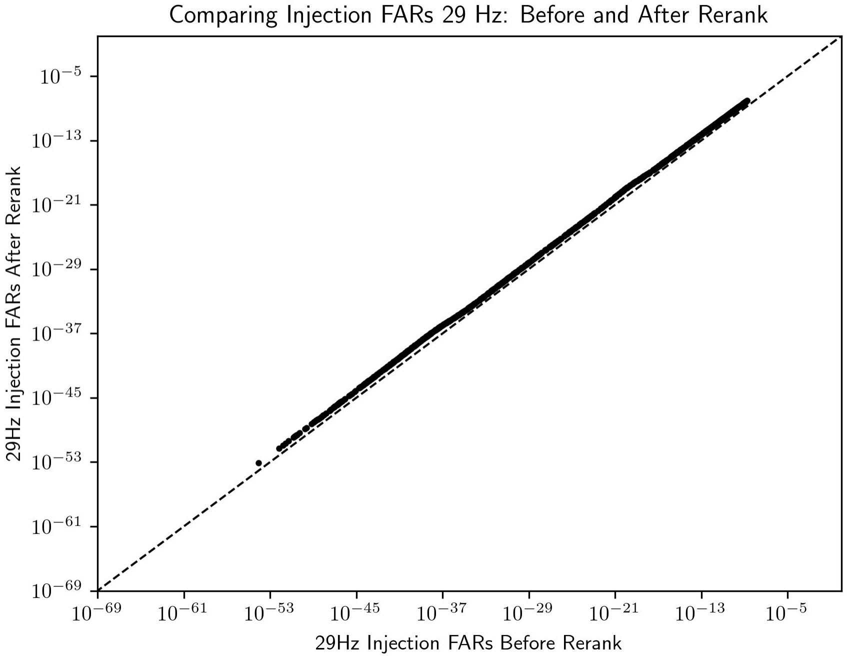


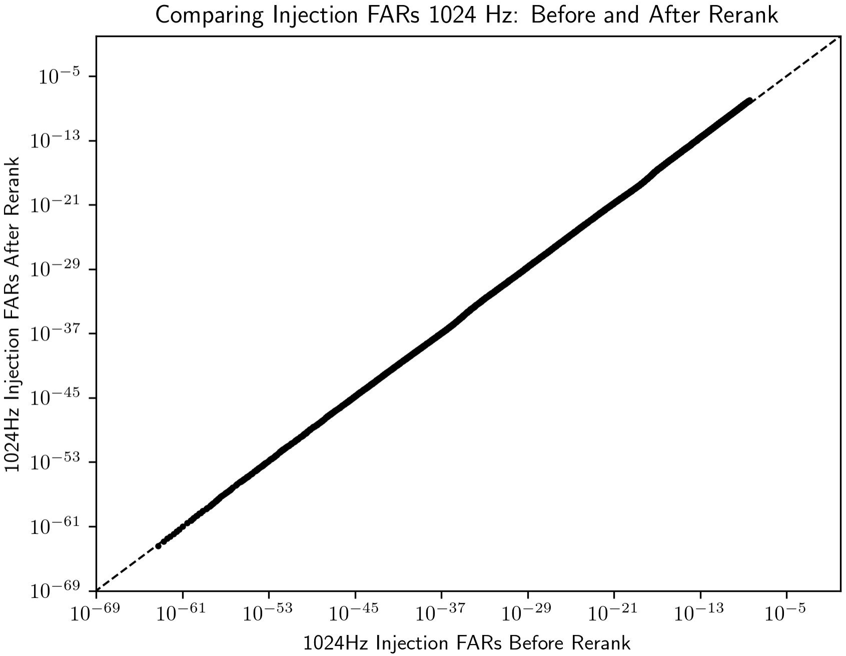
Image credit: Ryan Magee

How Does the False Alarm Rate Change?

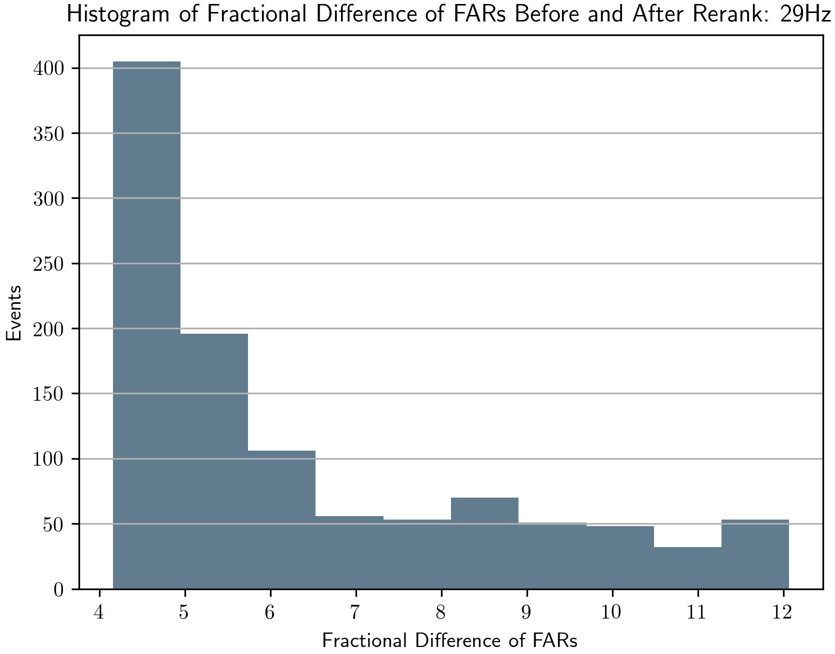
- To test how the false alarm rates change, we compare the single analysis and the three different analyses by combining the output files and reassigning the FARs
- We can track injections to see how confirmed signal-like candidates change
- For non-injections, we can observe how this process will change the noise-like data

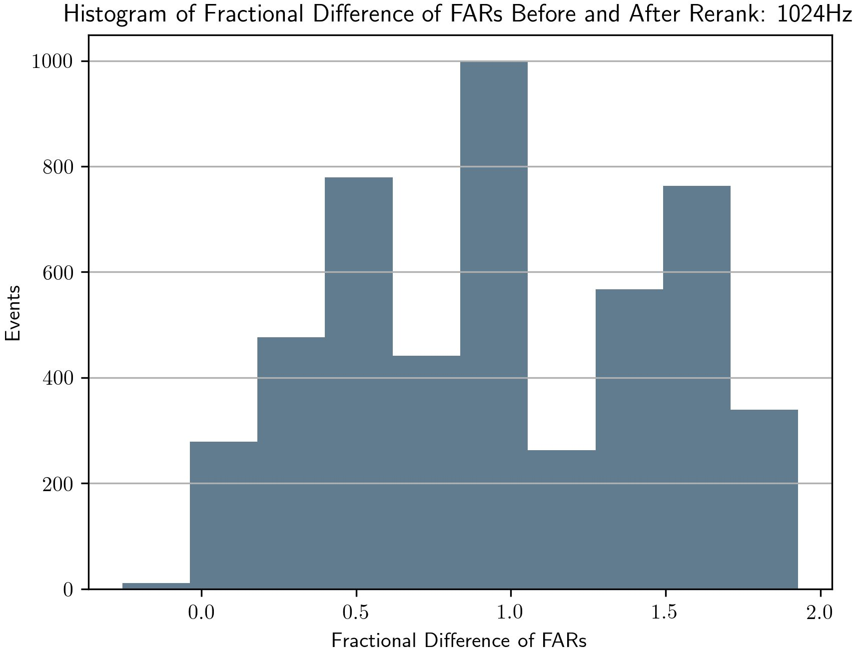
Comparing Injection FARs Before and After Rerank



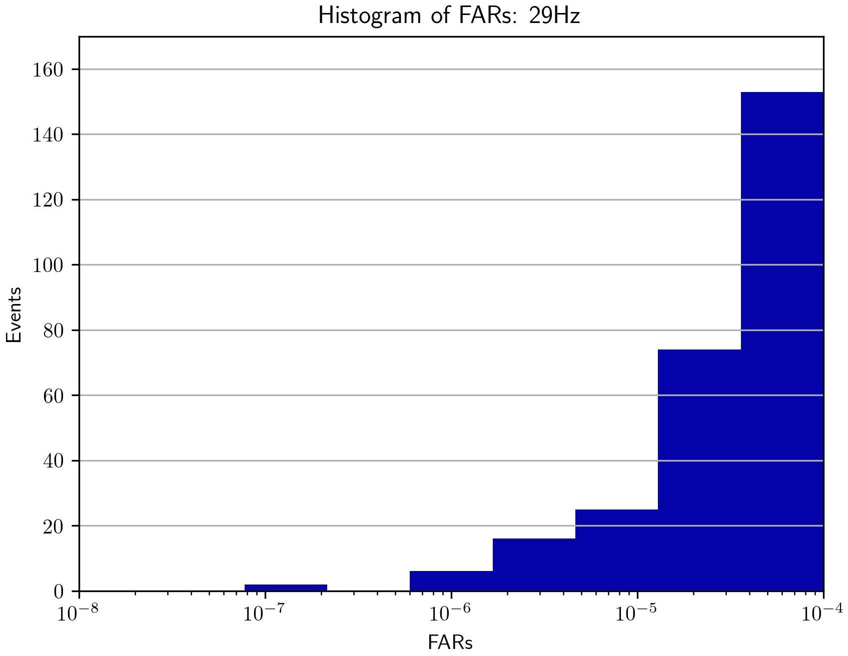


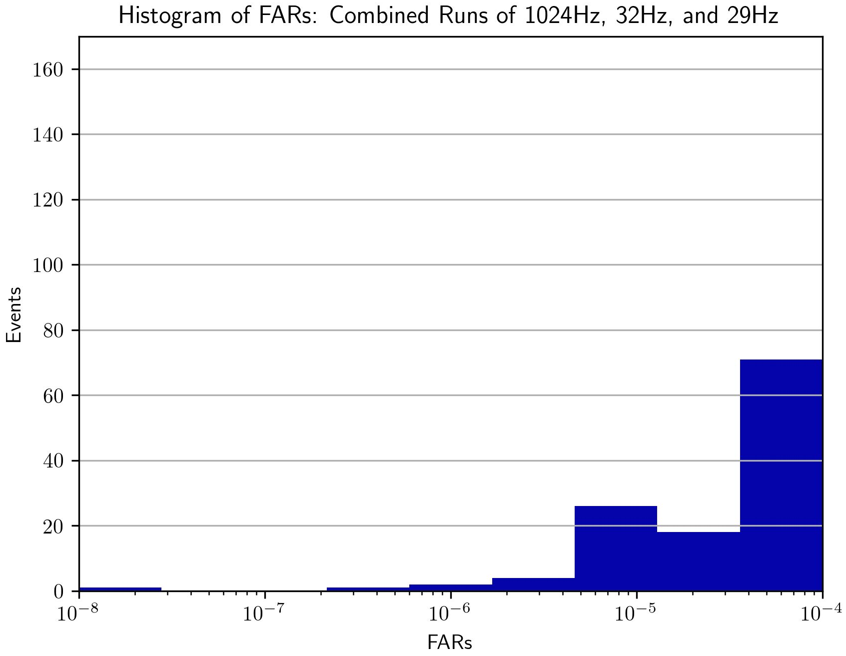
Fractional Difference of Injection FARs Before and After Rerank



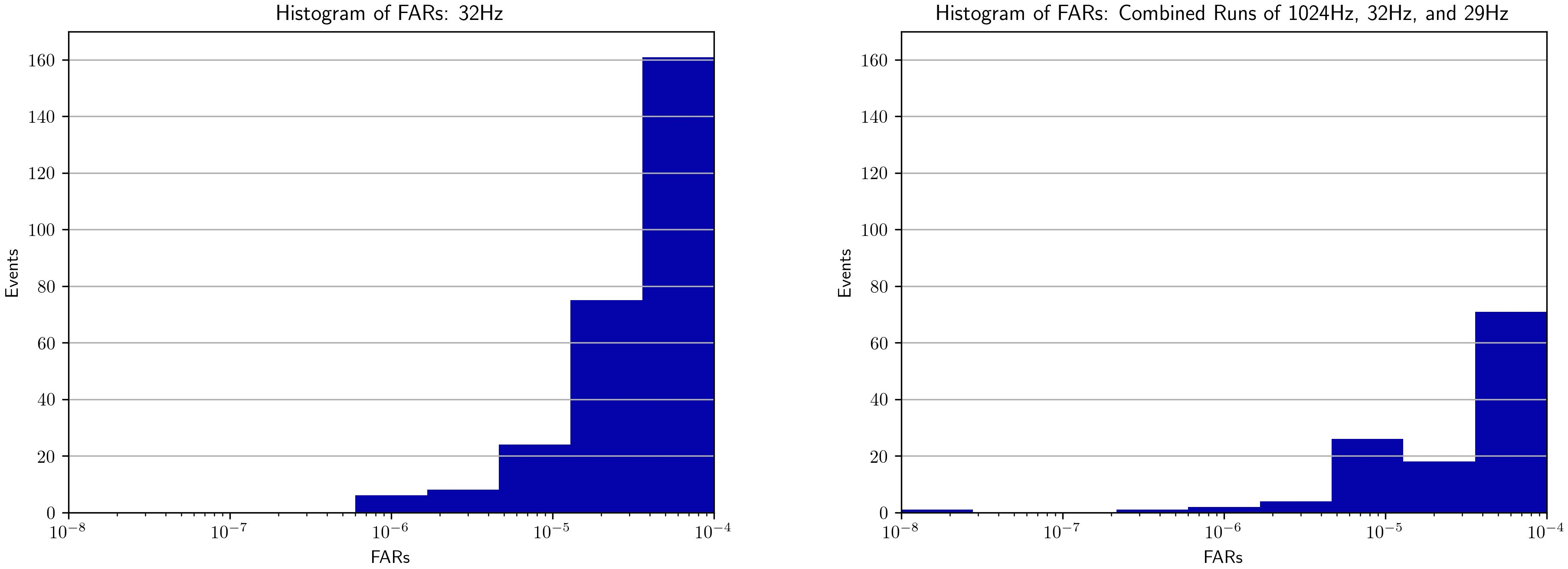


Comparing Non-Injection FARs: 29 Hz vs. Combined

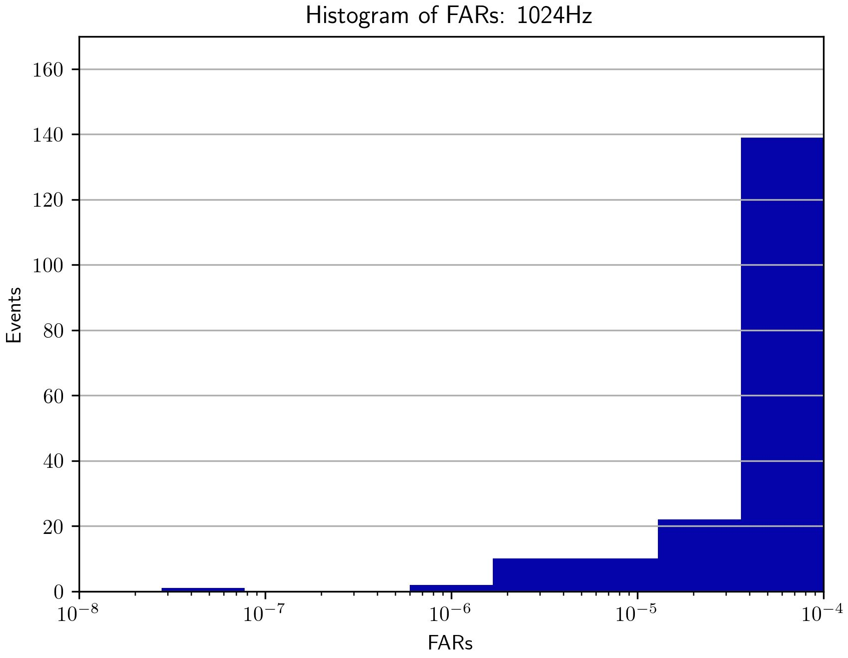

Histogram of FARs: 29Hz

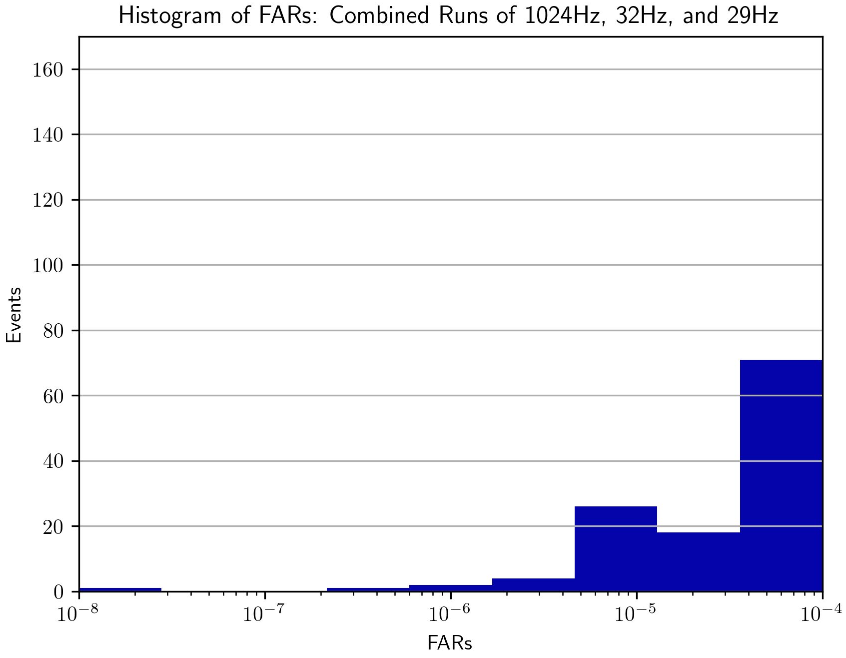

Histogram of FARs: Combined Runs of 1024Hz, 32Hz, and 29Hz

Comparing Non-Injection FARs: 32 Hz vs. Combined



Comparing Non-Injection FARs: 1024 Hz vs. Combined


Histogram of FARs: 1024Hz


Histogram of FARs: Combined Runs of 1024Hz, 32Hz, and 29Hz

Results

- From these analyses, we learned that this process did not hurt the search sensitivity
- This process could make some noise more significant, so we need to study this more
- This project has given us insight into how to reduce retractions for O4

Acknowledgements

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