NS Group Update

Burst Call Jan 21st 2015

James A. Clark for the NS group

Georgia Institute Of Technology

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The Group

Joining the group:

- Calls: bi-weekly, Friday **10am** EST, burst TeamSpeak channel
- https://wiki.ligo.org/viewauth/GIANT/GIANTteleconAgendas

Scope:

- Explore / discuss astrophysics & data analysis strategies pertaining to transient, unmodelled gravitational wave (GW) bursts from neutron stars (NSs)

Projects:

- Long bursts: Proto-magnetar deformations & Magnetar QPOs
- Short bursts: Post-BNS & magnetars
- . . . others welcome!

NS Search Proposal

Search proposal wrapped up and reviewer responses addressed:

- Current draft in DCC: https://dcc.ligo.org/LIGO-T1400606
- Reviewer comments / responses: https://wiki.ligo.org/DAC/NS

For O1 plan is to only target *extraordinary* events:

- Hyper-flares from Galactic magnetars (c.f., SGR 1806-20): X-pipeline & STAMP
- BNS: long bursts (STAMP / X-pipeline) from long-lived remnant, short bursts from short- or long-lived post-merger remnant

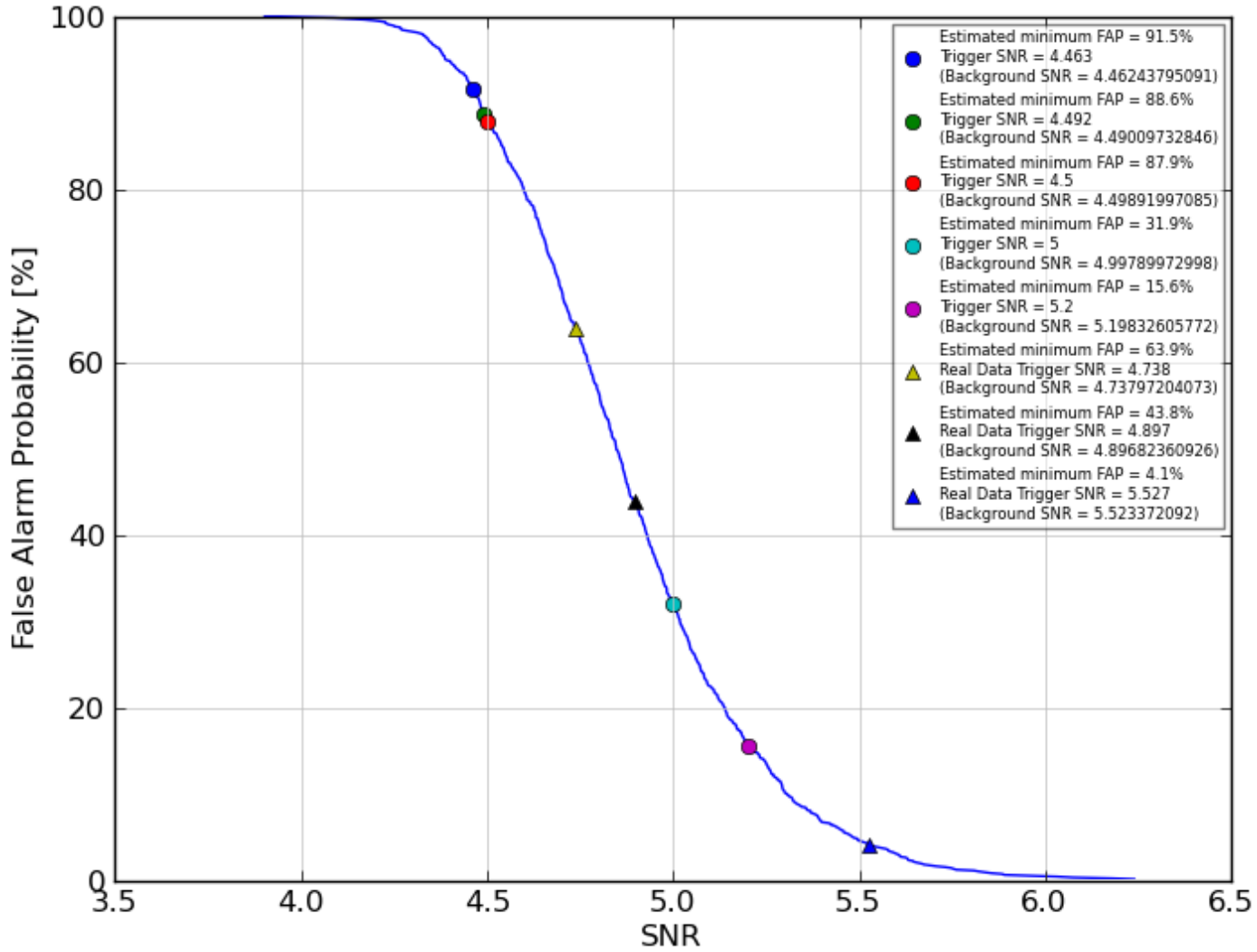
Review comments addressed, only substantive change: short post-merger analysis to be PE-style follow-up, not a search.

S6 Magnetar Analysis

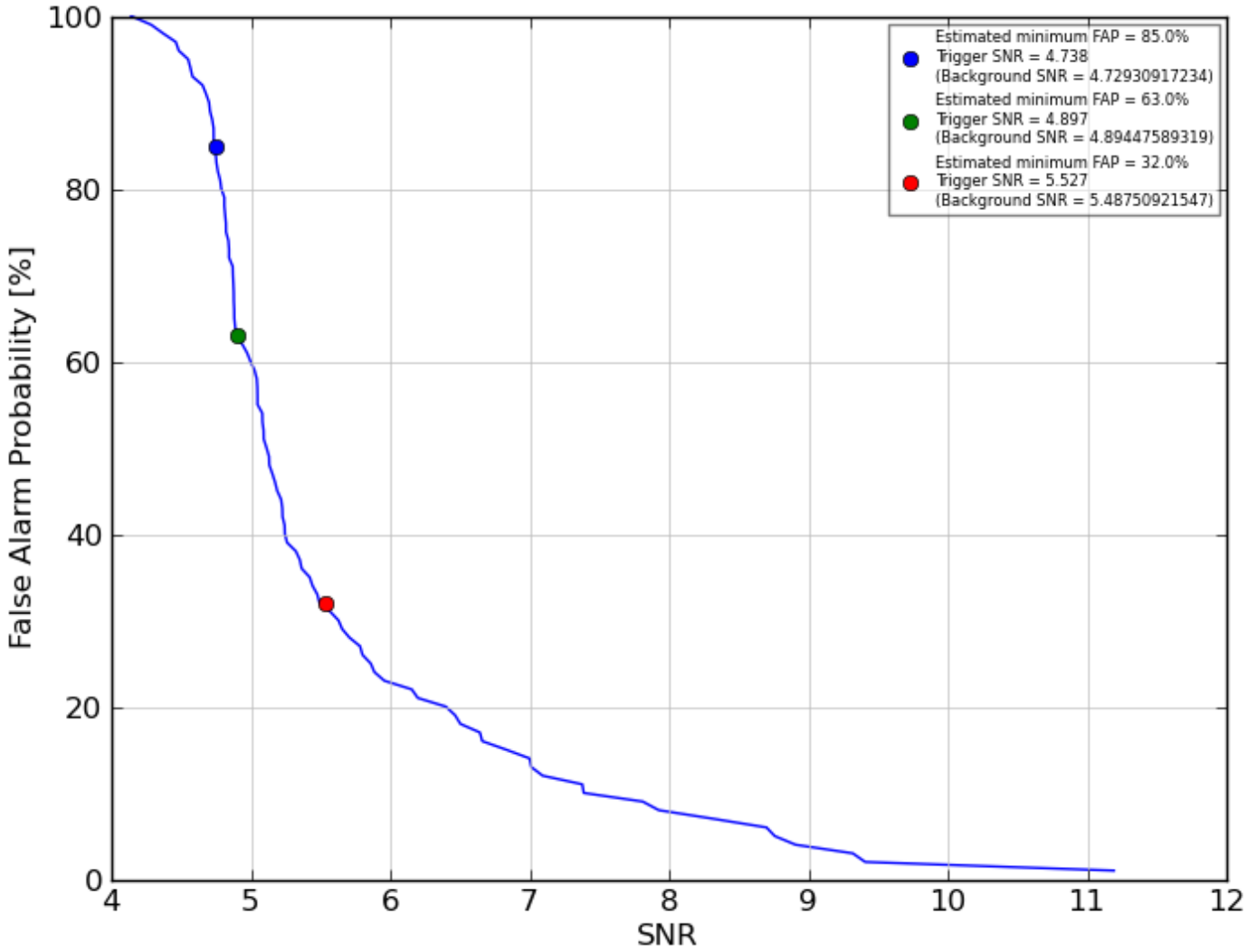
R. Quitzow-James: configuring & tuning STAMP for demonstration magnetar QPO analysis in S6 on 3 SGR bursts.

- Background studies: comparing STAMP trigger distributions (following slides) for simulated and S6 data. Investigating application of vetos to reduce distribution tails.
- Injections (sine-Gaussians, sines, ...) with $\tau \sim$ 10-100 s, frequencies guided by QPO observations to be used to determine energy upper limits.

STAMP background distribution: Gaussian noise



STAMP background distribution: S6 playground



BNS Long Burst Study

Preliminary MDC study to assess sensitivity to long-duration, slightly non-stationary signals from stable BNS remnants

- People: Michael Coughlin, Scott Coughlin, James Clark, Ryan Quitzow-James, Marie-Anne Bizourd, Nelson Christensen, Patrick Meyers, Eric Thrane
- Basic idea: BNS merger *may* result in a long-lived, massive neutron star; B-fields could result in quadrupole deformation (e.g., http://arxiv.org/abs/1408.0013)
- Signal: anti-chirp starting $\sim$kHz sweeps down in frequency over $\mathcal{O}(10^6)$ s
- Optimal search: 10–100 Mpc / 0.1–1 year^{-1}

BNS Long Burst Study: Example Waveforms

Example waveform evolution for signal @ 1 Mpc, typical stellar parameters and initial spin period 1 ms

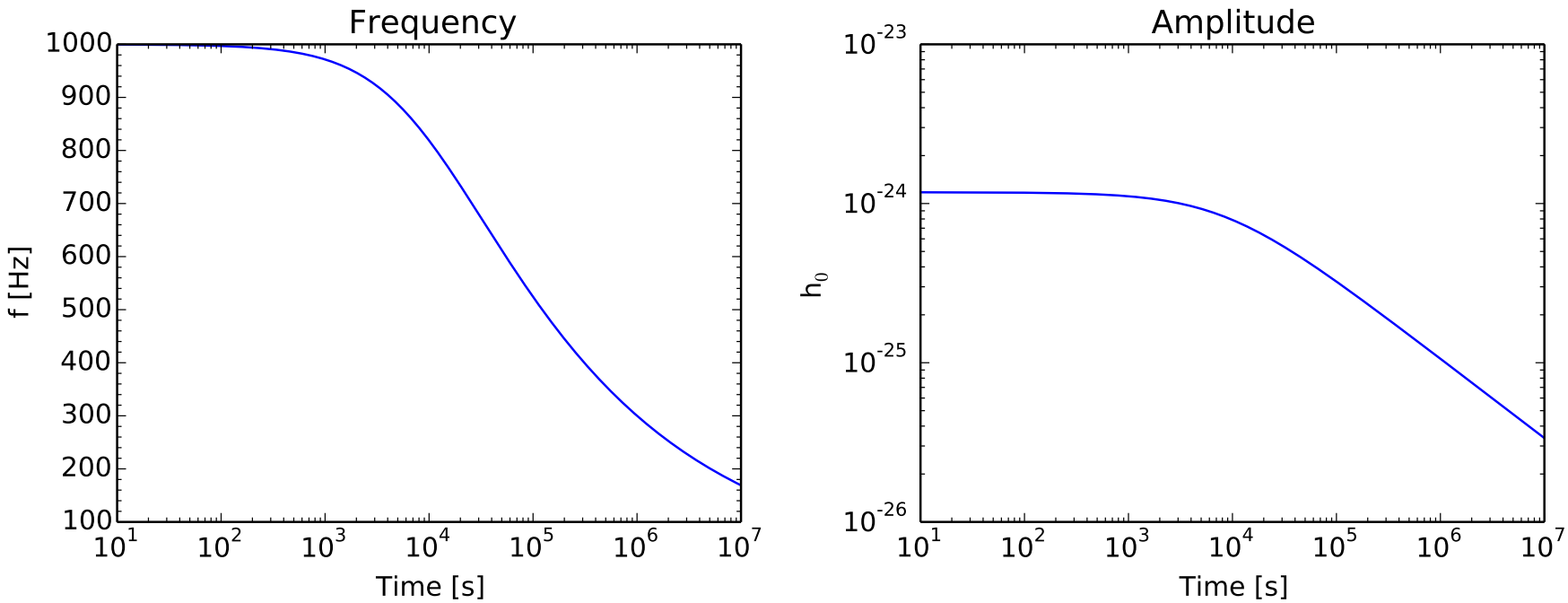


Figure 1: Created from http://arxiv.org/abs/1408.0013

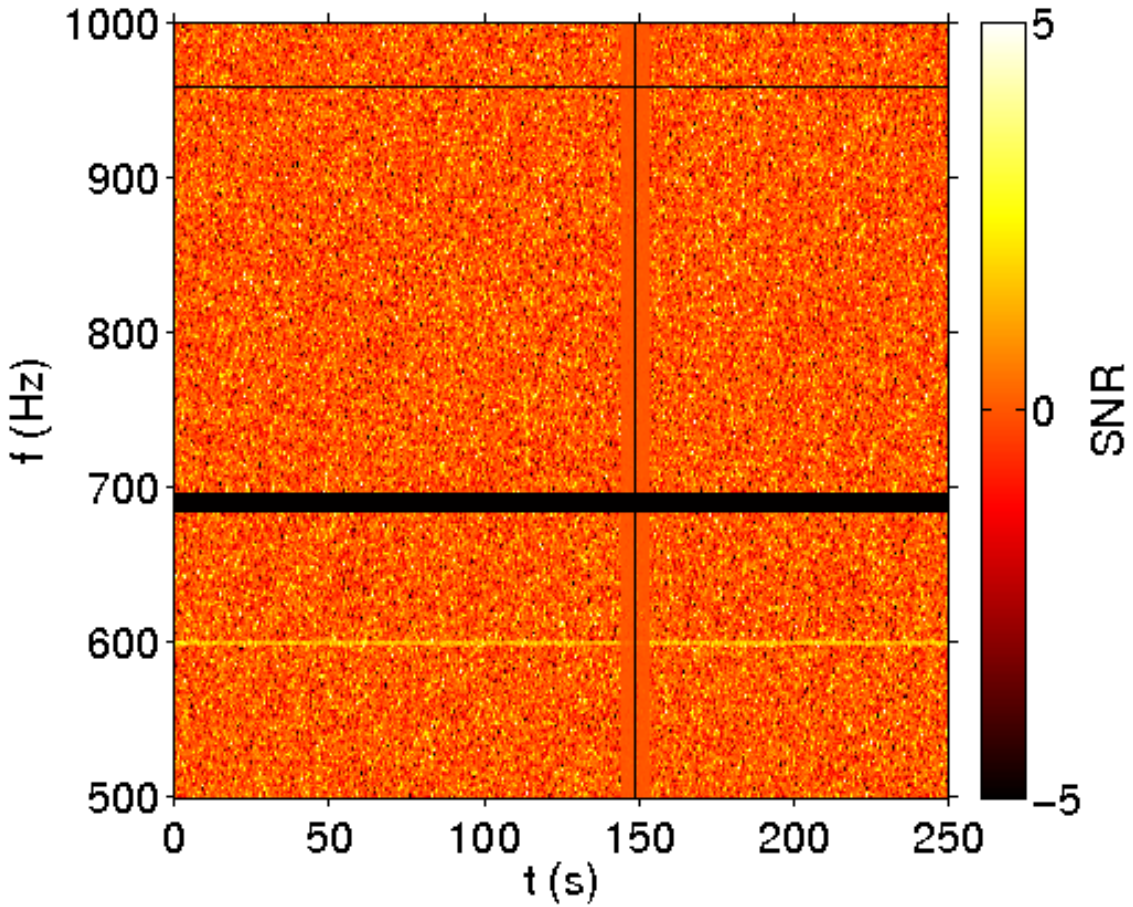
BNS Long Burst Study

Preliminary MDC study: $f = 600,\ 750,\ 900\,\mathrm{Hz}$ with $\tau = 5,\ 10,\ 50,\ 250\,\mathrm{s}$.

- Deploy simulation infrastructure appropriate for long signals: using swig-wrapped LAL routines in python module
- Using a week of S6 data as playground (GPS 946086263–946691063)
- Probe overlapping parameter space for X-pipeline[1] & STAMP
- Determine the longest duration of this signal we can actually see (i.e., at what point do we cease to accumulate SNR?)

[1] Spherical radiometer version

BNS Long Burst Study: Example STAMP Recovery



BNS Long Burst Study: *Preliminary* STAMP Results

- Use a background threshold corresponding to $\sim 1/10^4$ maps
- 50% FAP sensitivity (network) SNRs of
  - $f_0 = 600\,\mathrm{Hz}$, $\tau = 250\,\mathrm{s}$: $\rho_{\mathrm{net}} = 40$
  - $f_0 = 900\,\mathrm{Hz}$: $\tau = 250\,\mathrm{s}$: $\rho_{\mathrm{net}} = 40$
- Sensitivities seem reasonable for waveform duration and nature of clustering

Summary:

- Simulation infrastructure in place to inject & recover long, multi-frame signals in noise, common to multiple analyses
- Some preliminary sensitivity estimates for toy model
- Next: extent and explore toy models/parameters
- **Note**: several re-runs, refinements and X-pipeline results recently acquired

Post-BNS Short Bursts

Also developing BNS follow-ups targeting short, high-freq burst immediately after merger via (e.g.):

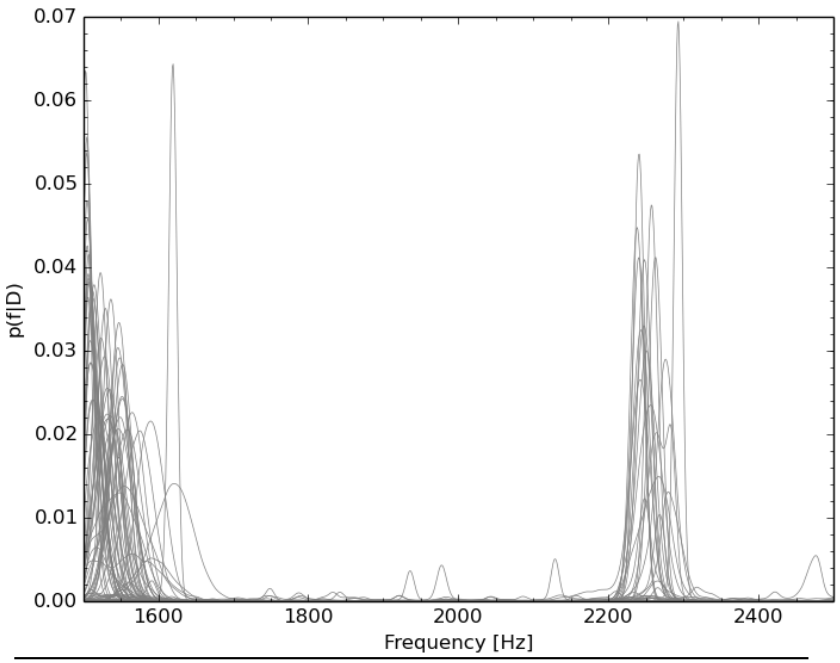
- Coherent WaveBurst: post-merger analysis via reconstructed time-freq map / PSD of reconstructed signal (similar to previous work)
- LALInference Burst (LIB): 'vanilla' LIB searches with sine-Gaussian templates, given a narrow time prior and returns (e.g.) signal/noise evidence, amplitude & frequency posteriors
- BayesWave: similar post-merger analysis to CWB

Some preliminary results from LIB & CWB analyses in-hand

LIB Studies

- Now have on-the-fly NINJA-style injections in LIB[2]
- Test run of 100 post-merger injections

  https://ldas-jobs.ligo-wa.caltech.edu/~jclark/LIB/pmns/shen_135135/lib_3.6-Mpc
- Frequency posteriors for injections with 10:1 odds of signal vs noise:



Target freq $\sim 2.25\,\mathrm{kHz}$. Problem: most runs only pick up the low-frequency content (May be resolvable through configuration or data conditioning choices, rather than templates)

[2]successful NINJA injections in LIB will also be useful for SNe

BayesWave & CWB Studies

Also beginning to look at CWB & BayesWave reconstructions[3] via CEDs of post-merger injections

Motivations:

- Point comparison of HF, structured waveform with PE tools
- Determine post-merger reconstruction fidelity, especially recovery of high frequencies
- Side project: how well can we determine inspiral/merger peak time? May be useful for guiding the LIB follow-up & interesting to compare CWB reconstructed peak time with CBC template's time-of-coalescence

[3] piggy-backing on McIver's SN reconstruction studies

CWB CED Example

https://ldas-jobs.ligo.caltech.edu/~jlmciver/reports/ADV_SIM_PMNS_SHEN135135_MR/ced/

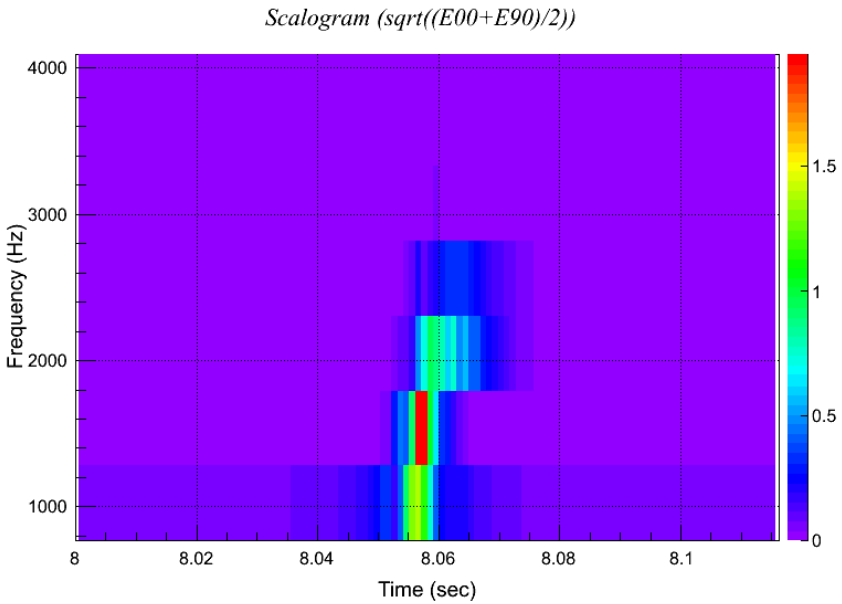


Figure 2: Injected

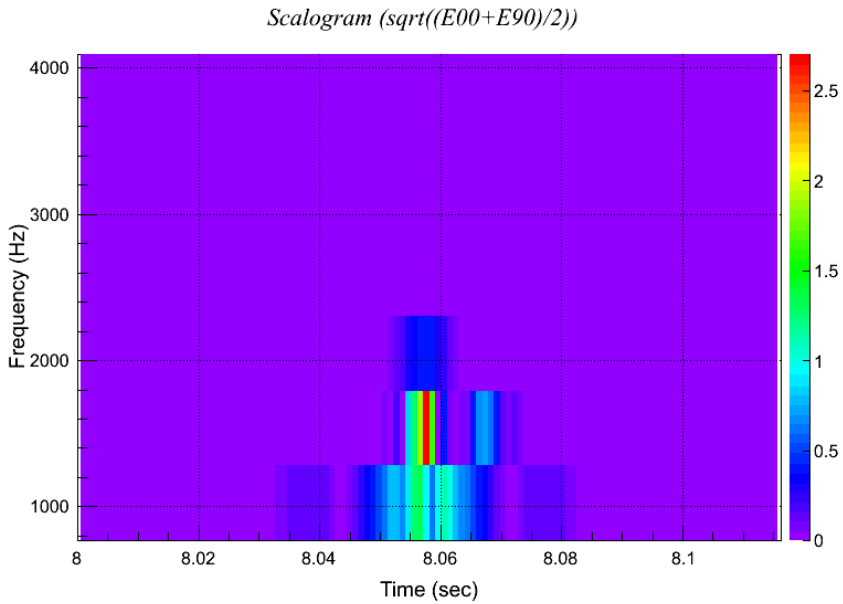


Figure 3: Reconstructed

Similar issues to LIB: high-frequency component is not robustly detected / recovered; improvements may be possible with clustering (TBD)

Summary

Group now quite active in addressing studies for follow-ups of extraordinary events in O1 (and beyond!)

- Infrastructure ∼in place for making MDC frames for common post-BNS long burst STAMP and X-pipeline studies
- Preliminary STAMP results for toy model post-BNS long bursts in hand and in line with expectation
- Prelim. LIB results for on-the-fly NINJA injections of short BNS bursts (infrastructure development)
- Prelim. Multi-res CWB 2G results for similar NINJA injections (via MDC frames but same functions as LIB)

Coming weeks: scale up all studies & develop necessary modifications/refinements to configurations and searches to better target astrophysical results