



Update on the Einstein Telescope BNS Mock Data & Science Challenge

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6th Einstein Telescope annual meeting, Lyon

Introduction

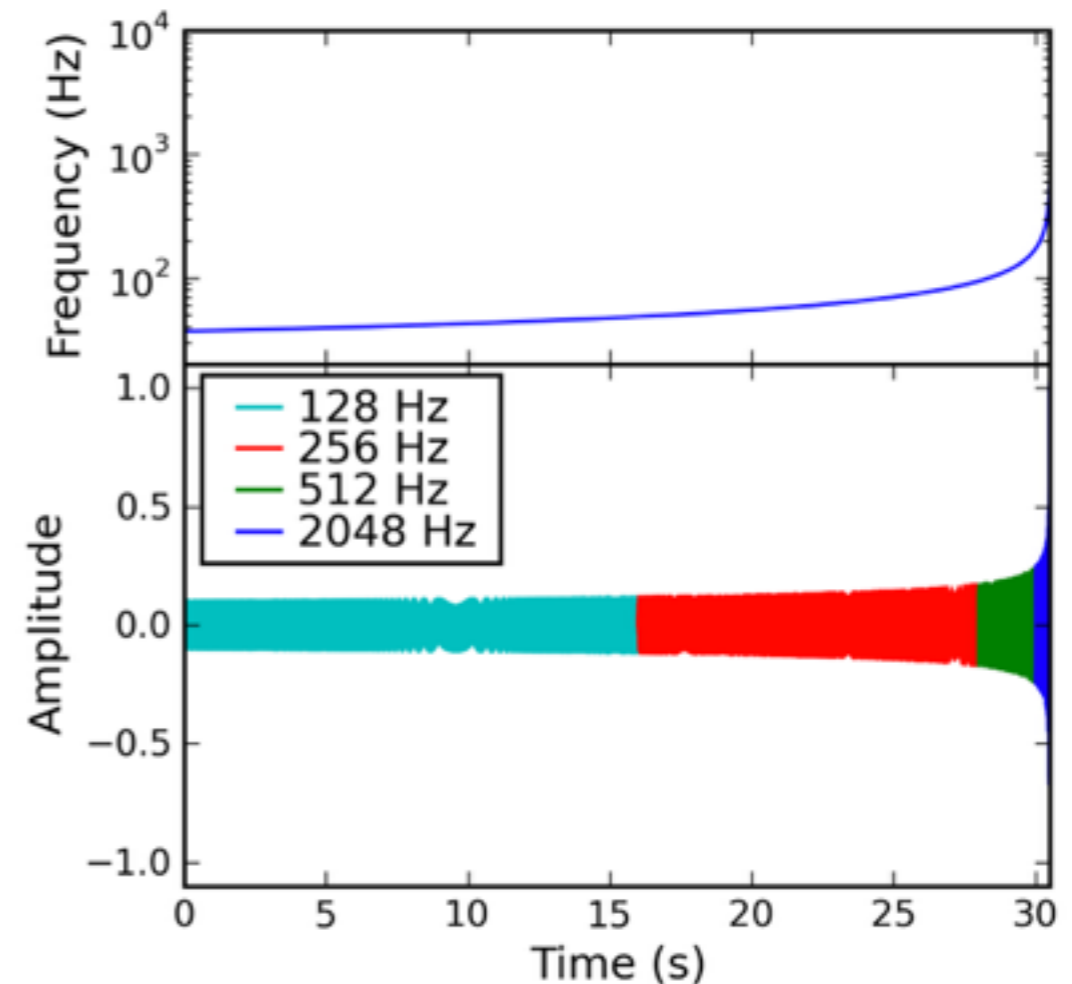
The second ET BNS mock data and science challenge aims to investigate several different areas:

- Analyse a full year of realistic data generated for the three detectors containing a large number of different sources.
- Test a new low latency analysis pipeline, `gstlal`, to be able to detect multiple signals using templates starting at low frequencies.
- Perform parameter estimation to recover the injected signal parameters when the signals overlap each other across multiple frequency bands.

gstlal: A new low latency matched filtering pipeline

Developed as the advanced detector online CBC analysis pipeline.

- Uses gstreamer technology.
- Able to analyse down to low frequencies by down sampling at lower signal frequencies ~ 5 or 10Hz
- Reduce number of templates used via use of singular value decomposition (SVD) ~ 10%
- In the online search has very low latency ~ 30s



For more information see:

<https://ldas-jobs.ligo.caltech.edu/~gstlalcbc/doc/gstlal-0.7.1/html/>

<https://ldas-jobs.ligo.caltech.edu/~gstlalcbc/doc/gstlal-inspiral-0.3.2/html/>

Source: S. Privitera LIGO-G1000153-v2

Initial testing

The main mock data sets have already been described by Tania Regimbau. In preparation for analysing this I have been using smaller data sets to test the performance of gstlal.

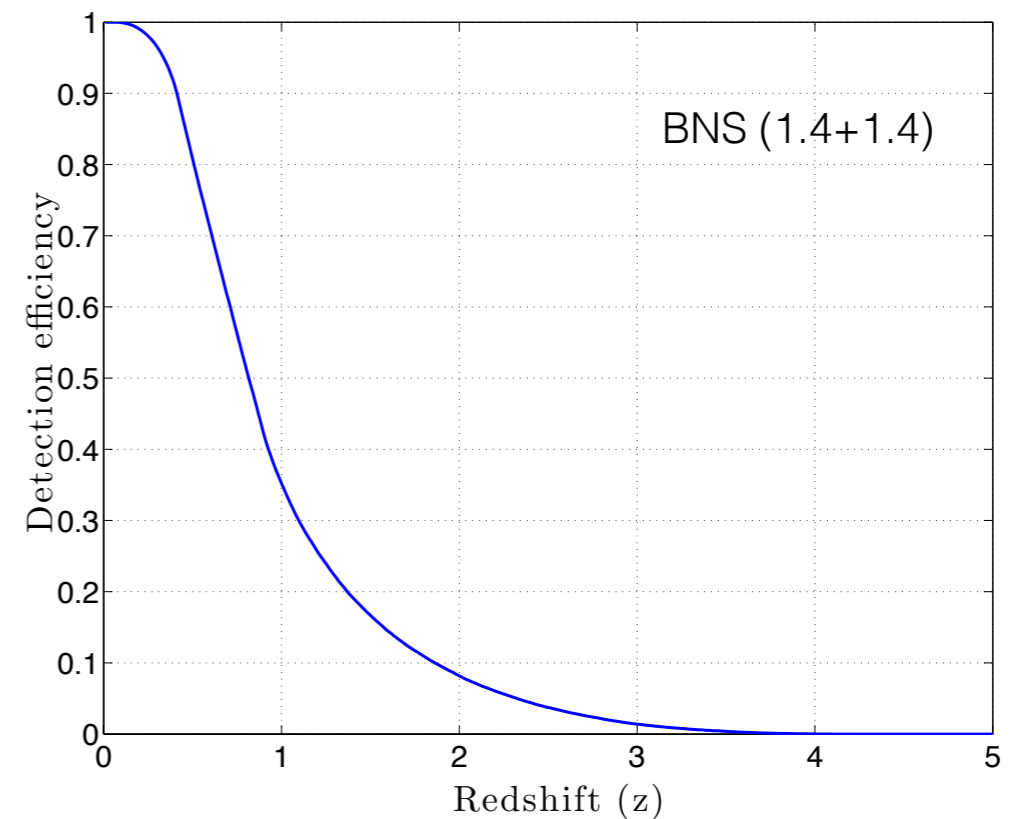
- 2 data sets using different coalescence rates giving an average time between signal arrivals of 12.5s and 125s. (Set 1 - 14791 events, set 2 = 1450)
- Length of data = 204800s ~ 2 days 9 hours
- BNS Mass distribution = [1.15, 1.65] M_{\odot} , mean = 1.4 M_{\odot} , sigma = 0.05 M_{\odot}
- Separated detector locations accounted for.
- Theoretical SNR is calculated for each event.

$$\rho_A^2 = \frac{5}{6} \frac{(GM^z)^{5/3}}{c^3 \pi^{4/3} D_L^2} \int_{f_{min}}^{f_{LSO}(z)} \frac{\mathcal{F}_A^2 f^{-7/3}}{S_n(f)} df$$

Search parameters

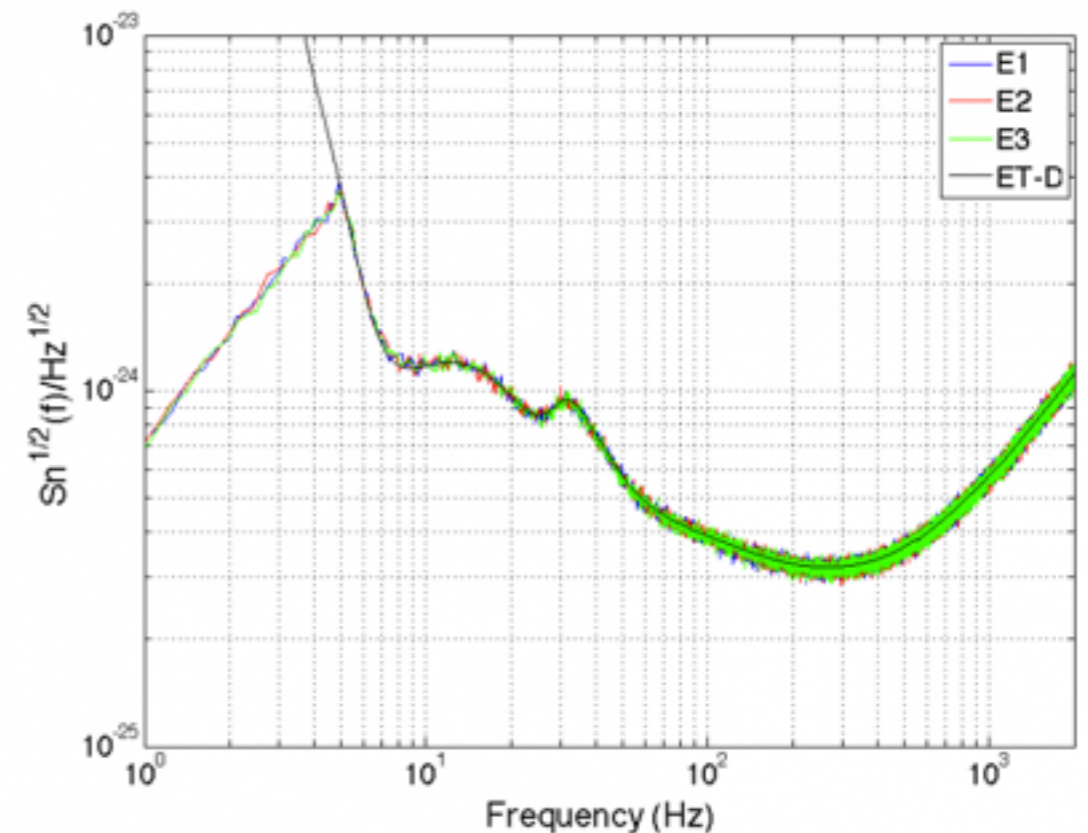
- Need to account for the redshifting of the masses ($z_{\max} = 4$), significantly increases the search mass range.
- Single mass range = $[1.125 \ 8.5] M_{\odot}$
- Total mass range = $[2.25 \ 17] M_{\odot}$
- Symmetric mass ratio range = $[0.25 \ 0.242]$
- Low frequency cut-off = 20 Hz
- Templates produced with TaylorF2 waveforms.
- Produces 13165 templates.

$$m_{\text{obs}} = m (1+z)$$



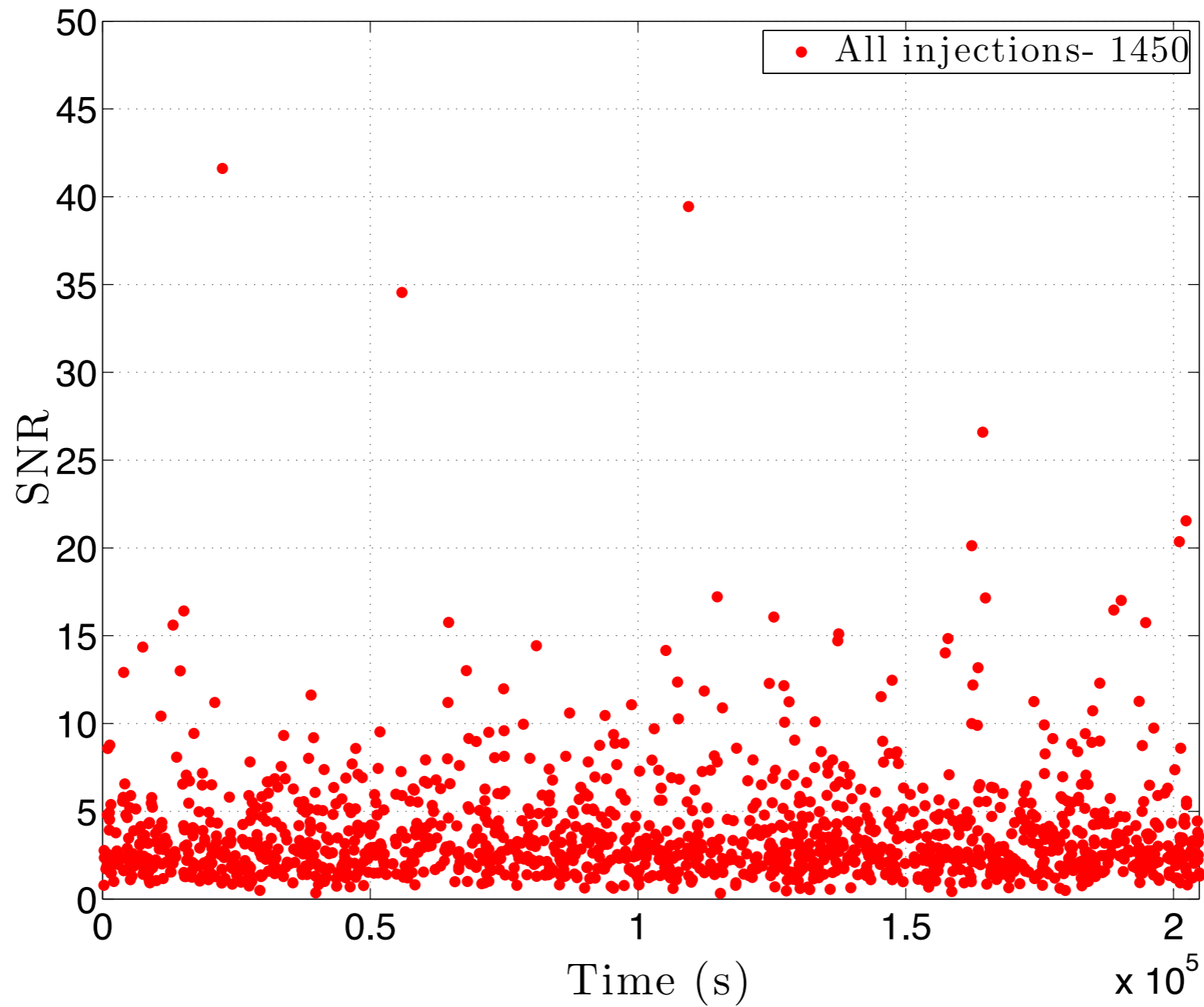
Running gstlal

- The main analysis is very automated with use of Makefiles.
- Only consider triple coincidence detections
- The analysis on ET data fails after producing a list of trigger - expected.

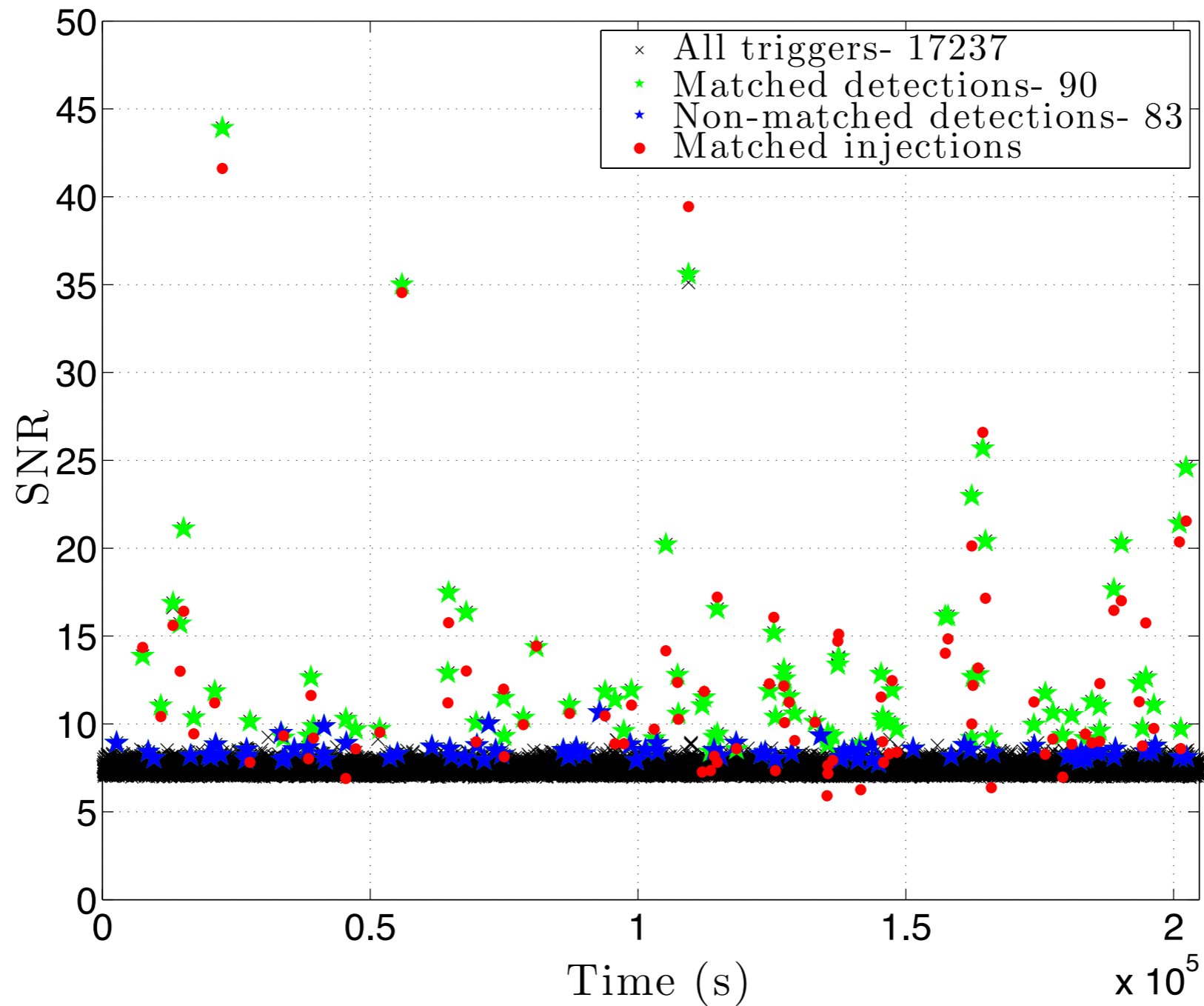


For details on how install and run gstlal, see:
https://gravity.astro.cf.ac.uk/dokuwiki/collaborations/et/etmdc_gstlal

Running the analysis: Injected signals

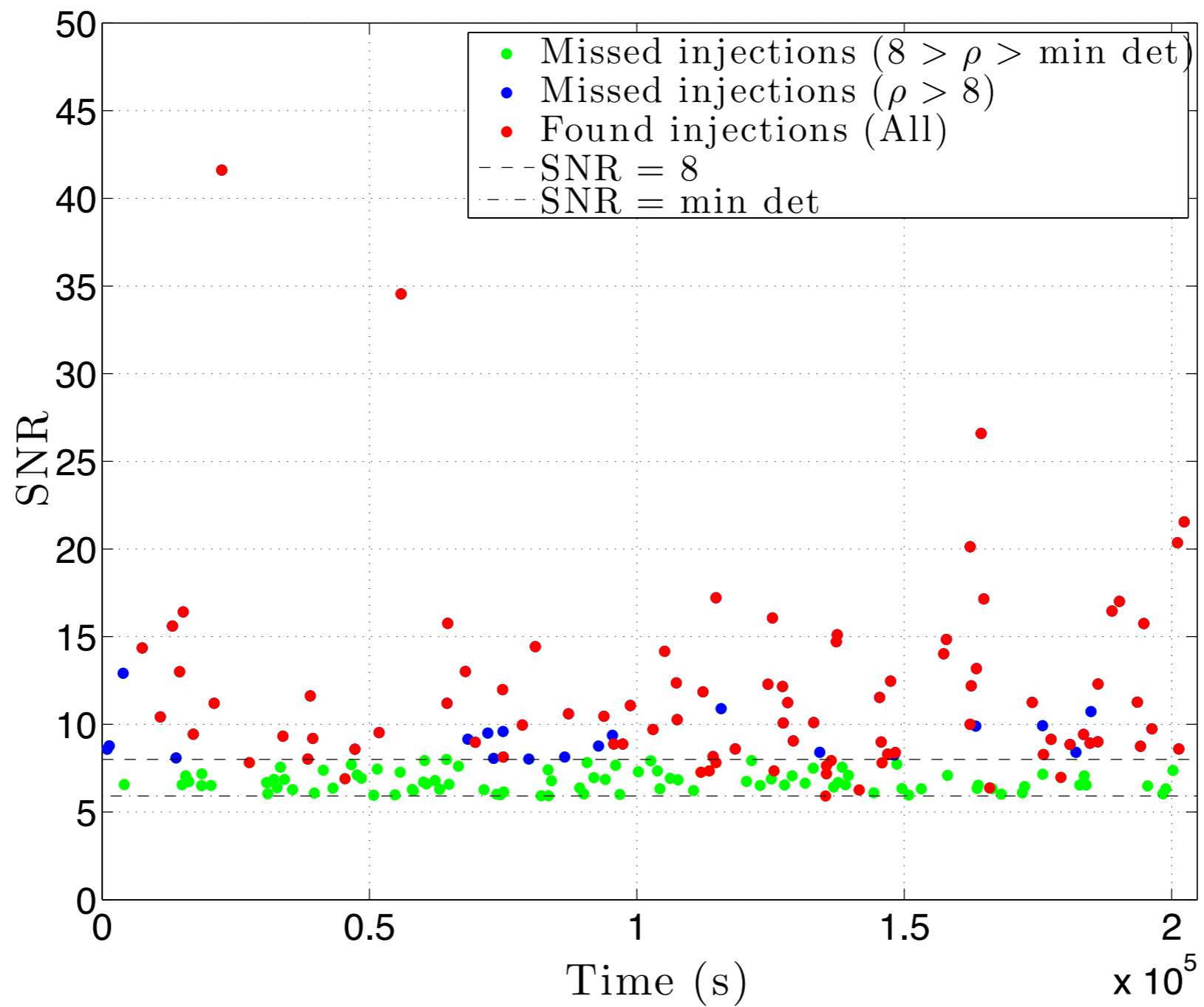


Running the analysis: Triggers with detections



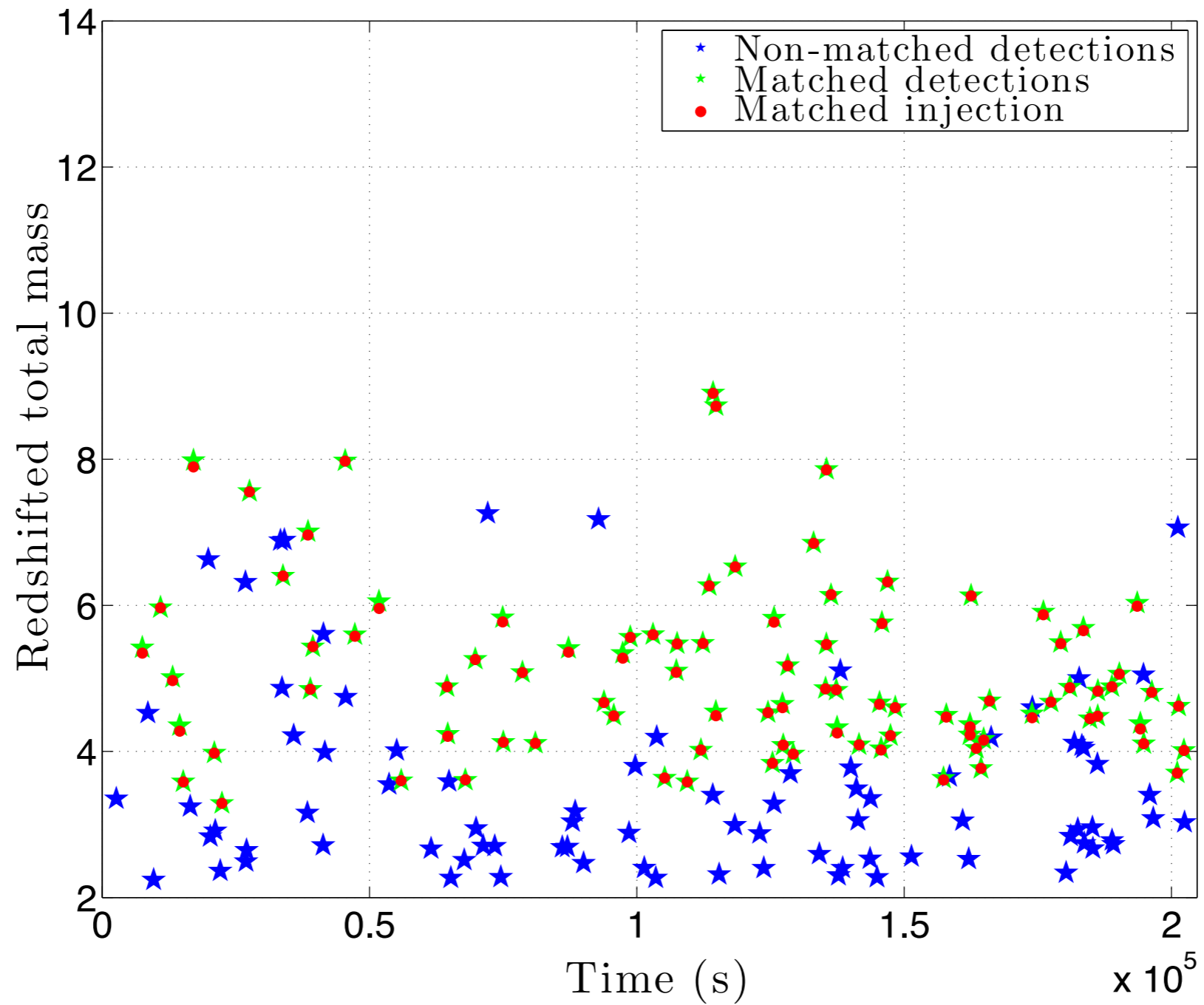
Time-SNR

Missed/Found



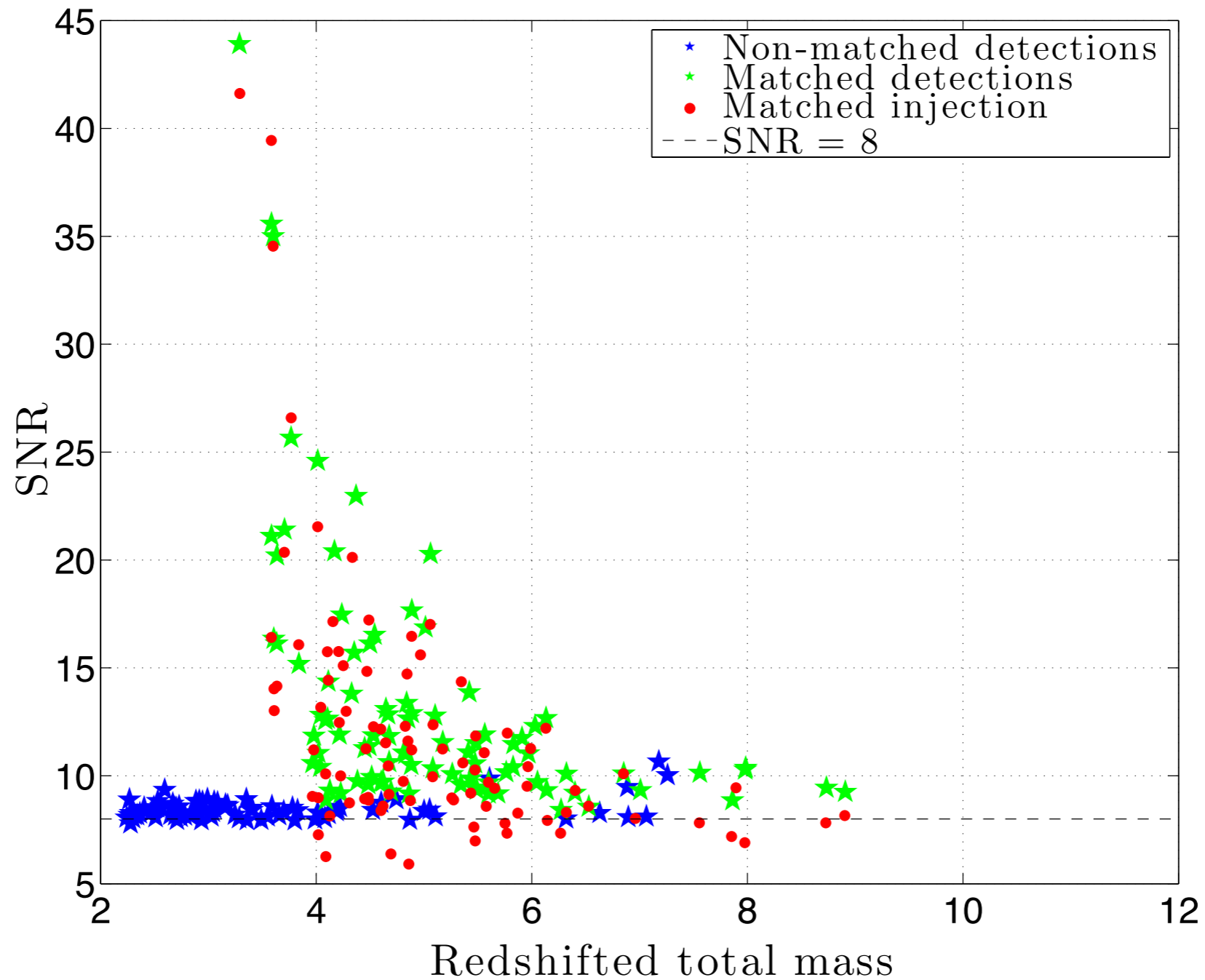
Time-Mass

Matched/Non-matched



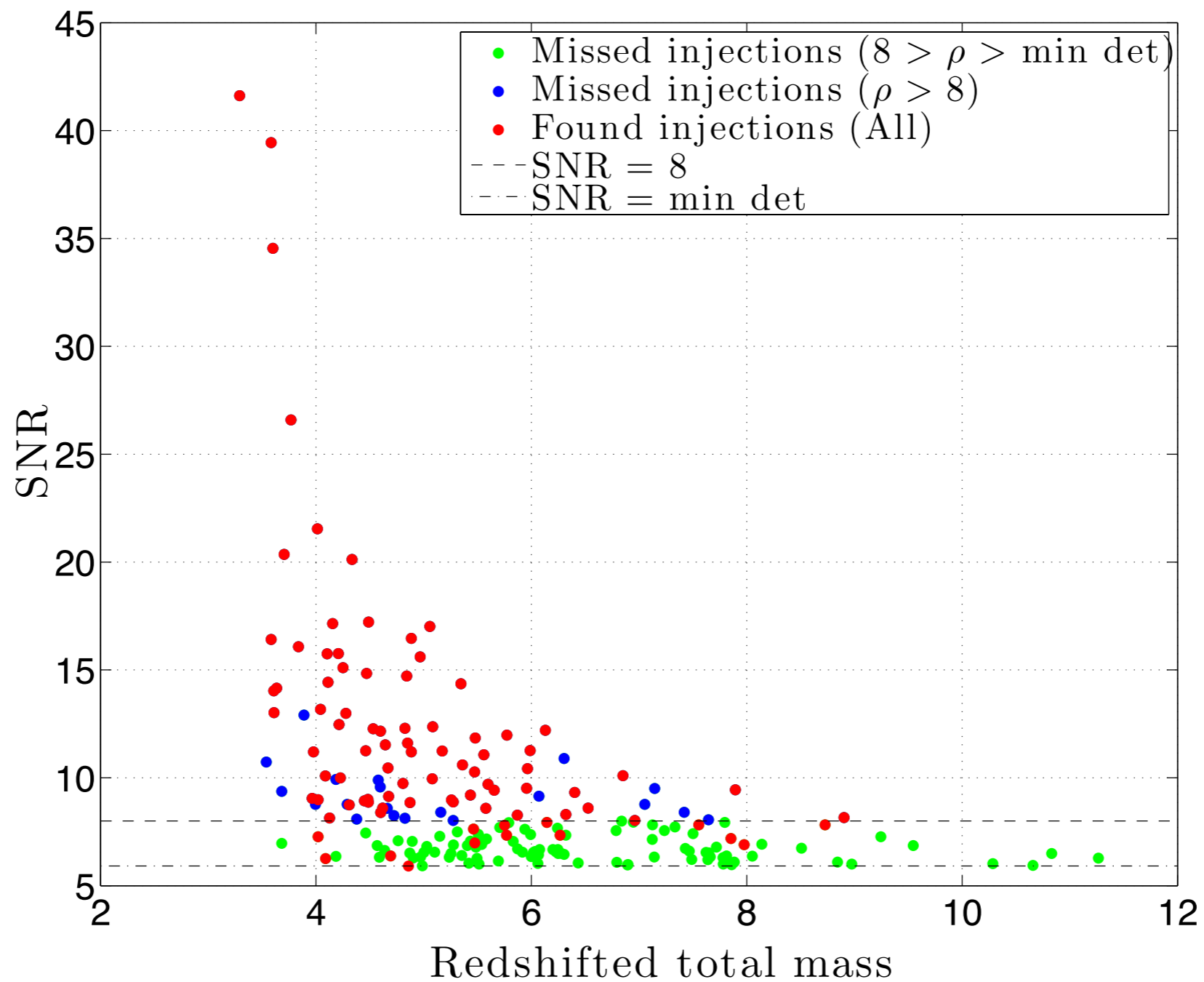
Mass-SNR

Matched/Non-matched



Mass-SNR

Missed/Found



Missed/Found injections

- Set 1

Number of signals injected = 14791

Number of injections with SNR > 8 = 900

Number found = 786

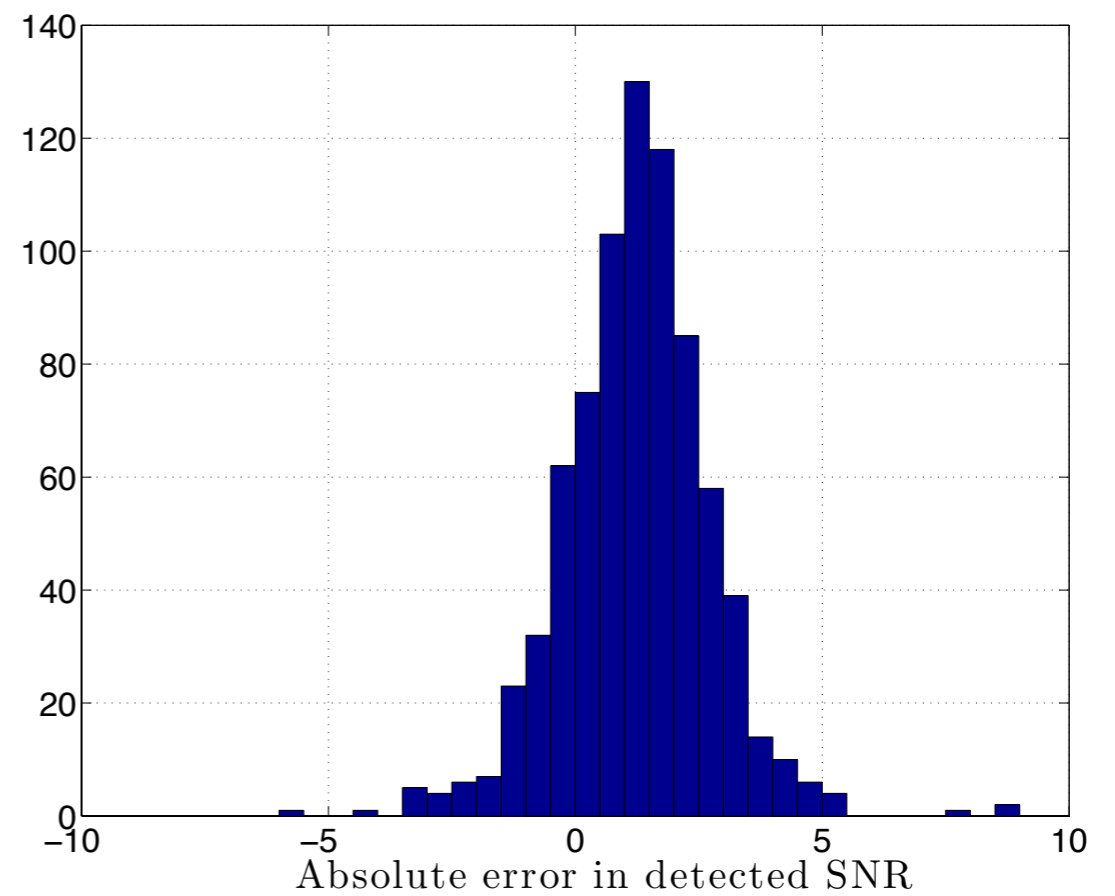
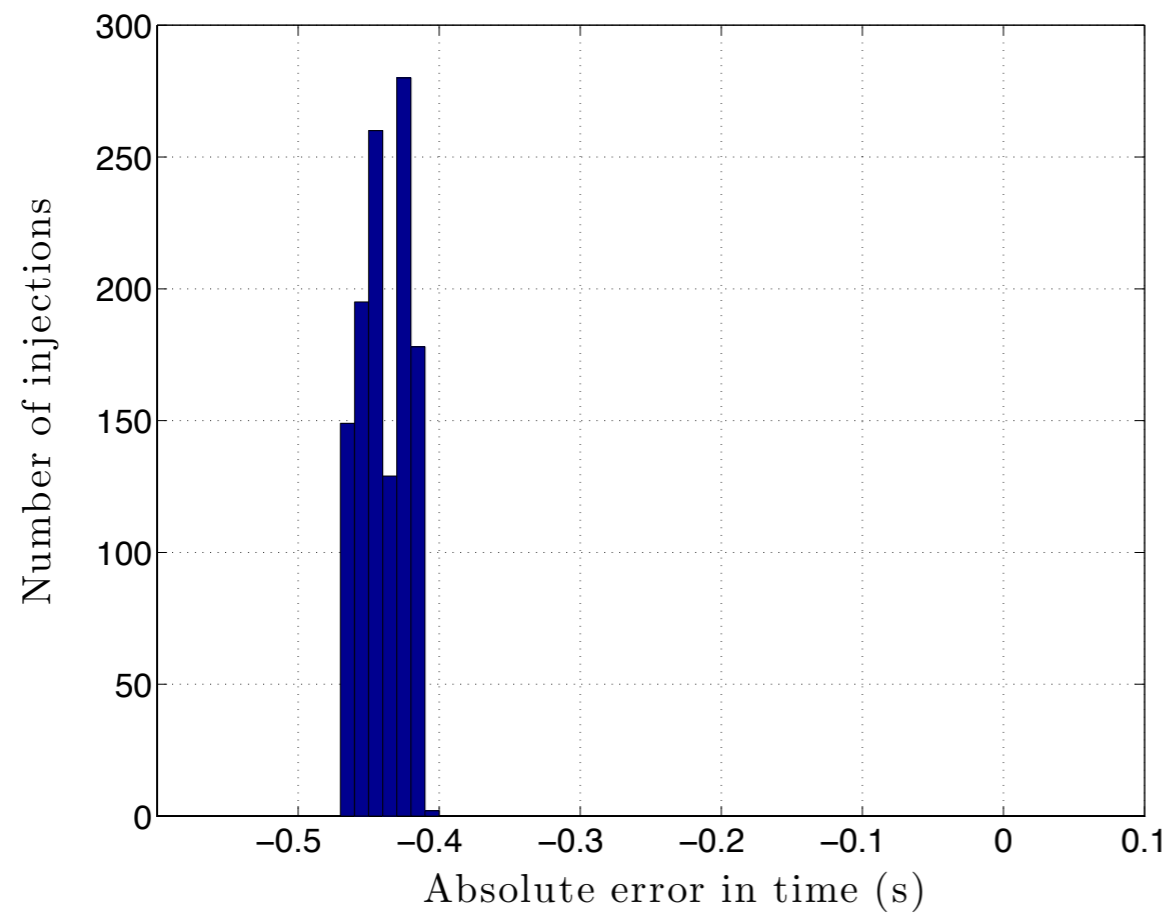
- Set 2

Number of signals injected = 1450

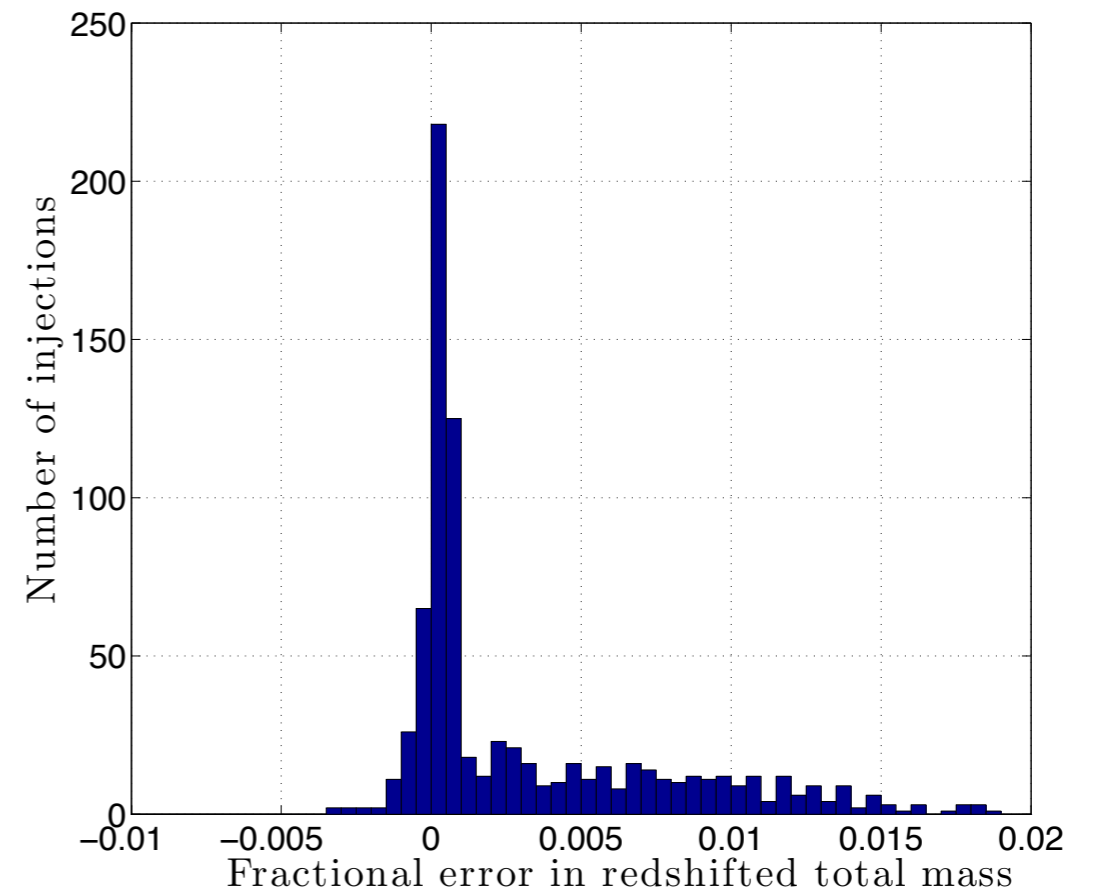
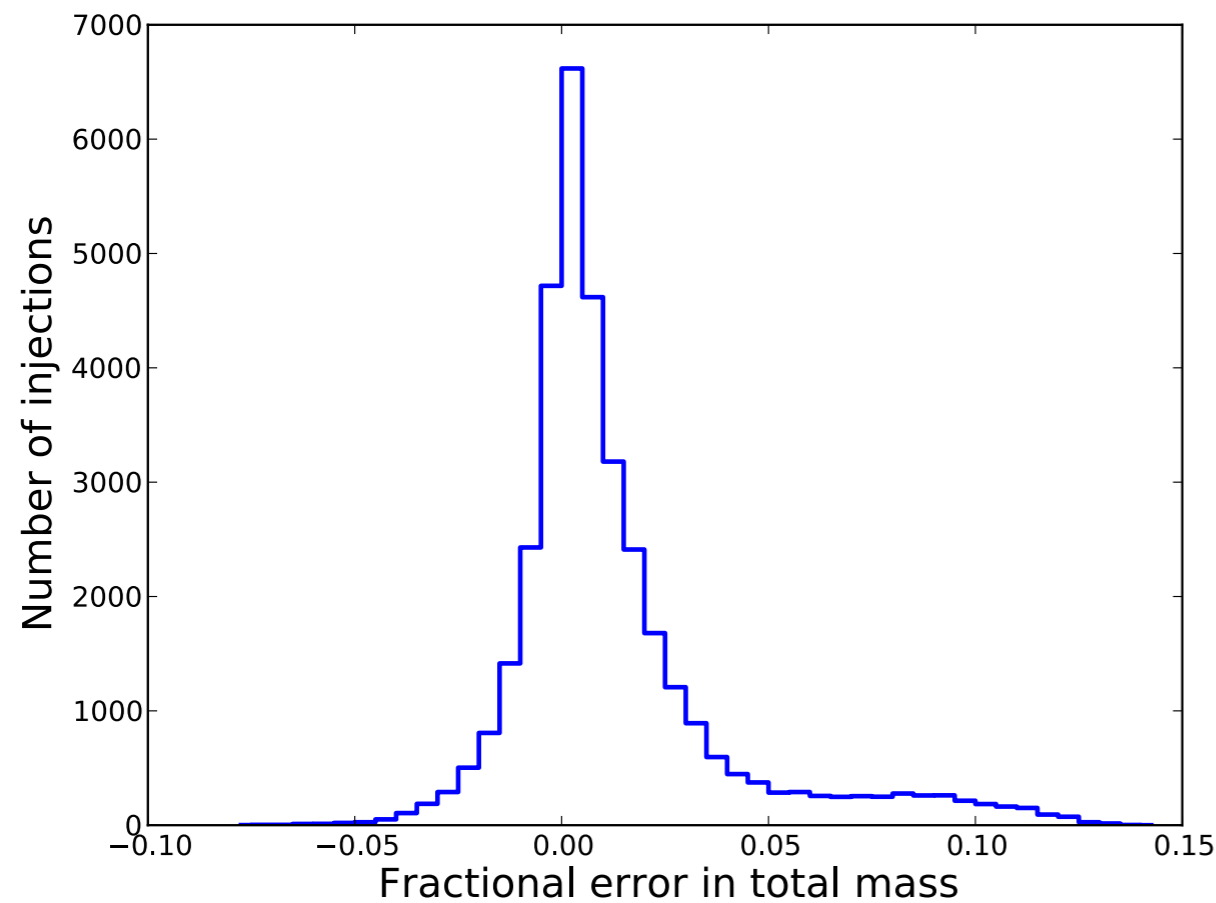
Number of injections with SNR > 8 = 96

Number found = 90

Error in recovered parameters

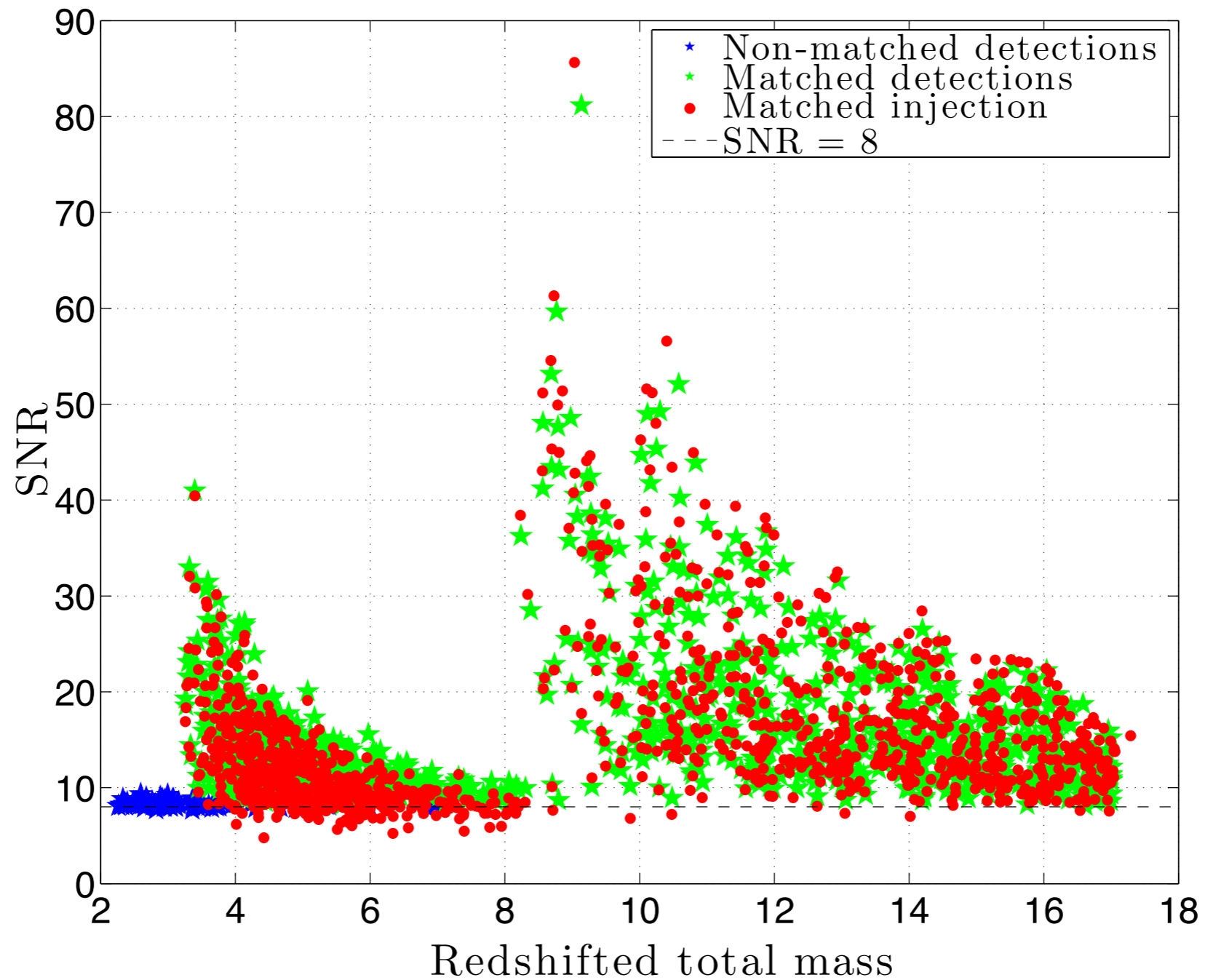


Comparing recovered mass error with first MDC



BNS + BBH

Matched/Non-matched



Future tasks

- Analyse full year of mock data containing different sources of signals.
Will commence soon, waiting for ER6 package releases.
- Run MCMC parameter estimation on initial data sets.
Planned to be carried out in the next month.
- Improved clustering of triggers to detect near threshold events.
In progress.
- Use of null stream to calculate the false alarm probability of detections to remove false events.
No work has been done yet.
- Analyse data down to lower frequencies, i.e. 5Hz.
Done! But for a very small mass range, has high computing requirements.
- Investigate the use of glitchy noise (with use of recoloured S5 data).
The tools for this are contained within gstlal.

5Hz analysis

- Analysing data starting at 5Hz is possible but is very memory intensive
- Has been run searching for a single loud event. Time and mass were correct but SNR was off.
- A lot more work is required.
- The main mock data set will not be analysed down to 5Hz.

Number of templates

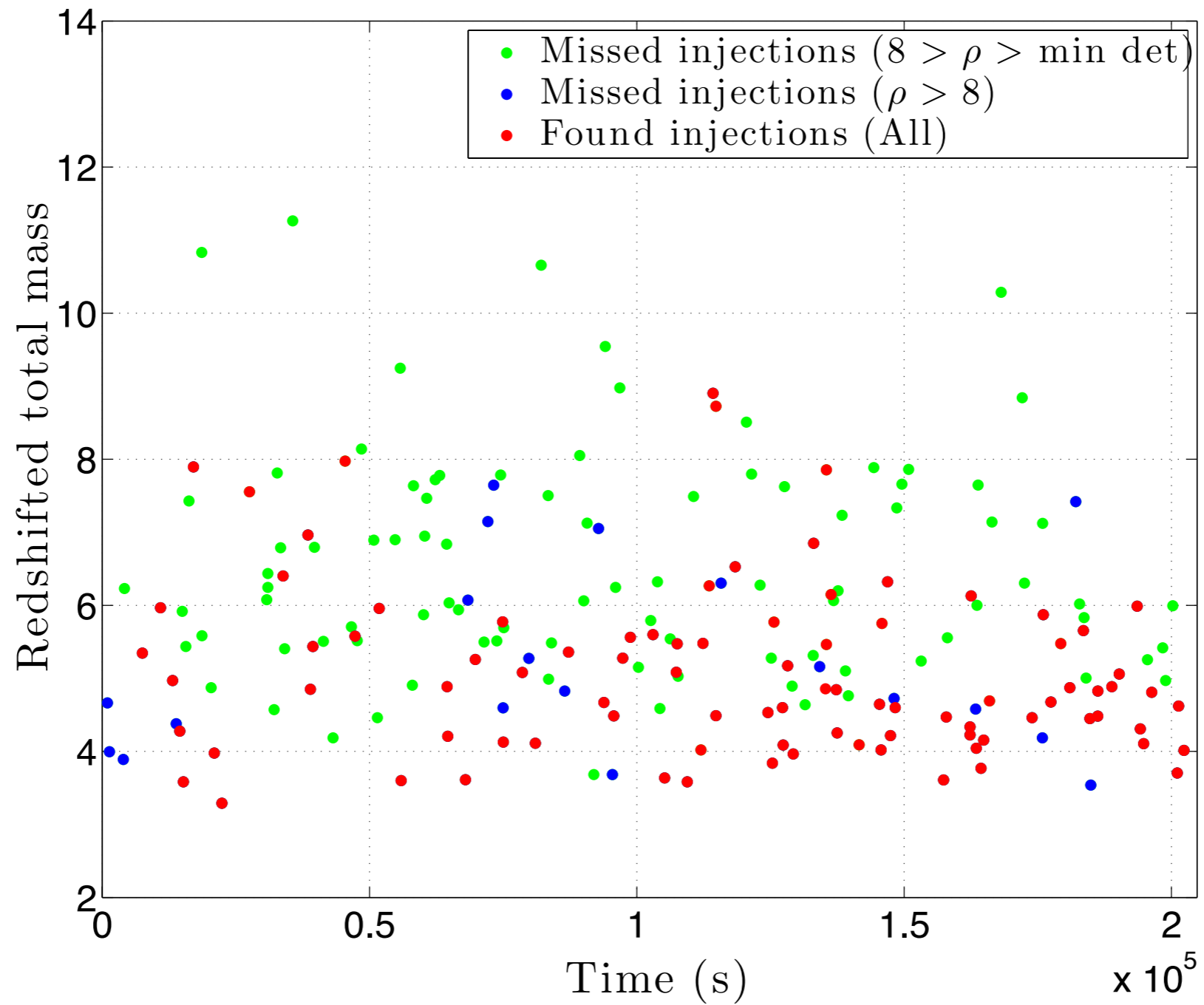
f_low	Small mass range	Full mass range
20 Hz	2138	23492
10 Hz	7966	130797
5 Hz	23849	516643

Summary

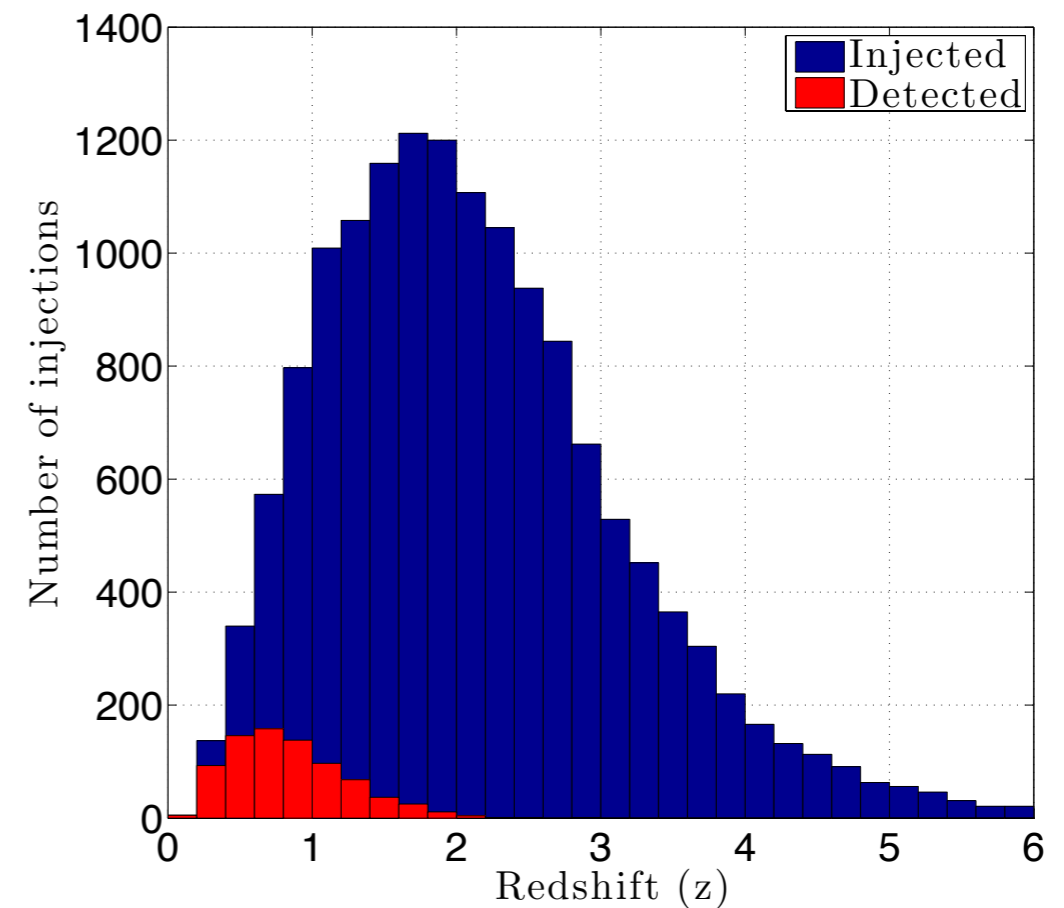
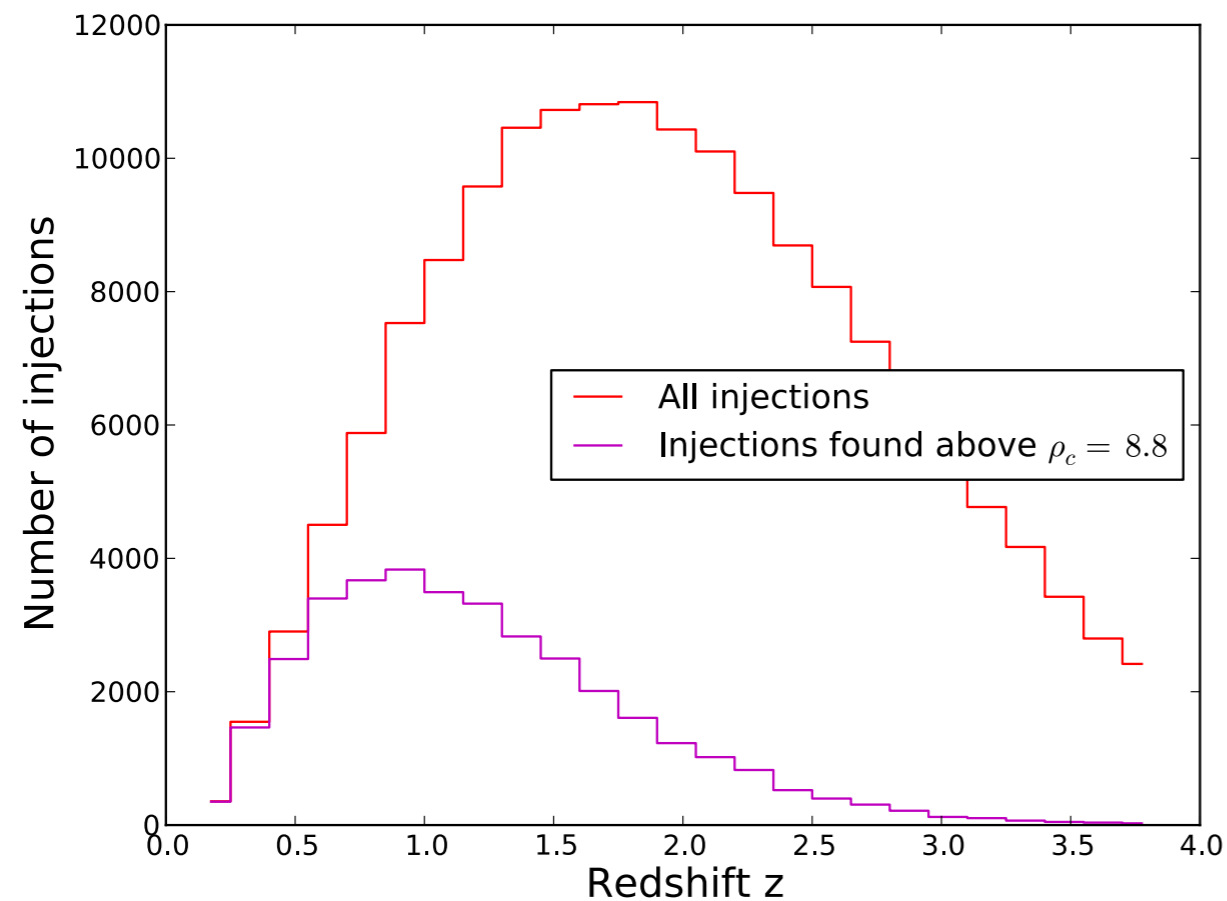
- Able to analyse mock ET data and detect most loud events using gstlal. Weaker signals are less certain but this can be improved with better clustering.
- Work still needs to be done on several areas (clustering of triggers, use of null stream, investigating glitchy data).
- Ready to begin analysing the main mock data set!

Extra slides

Time-Mass Missed/Found

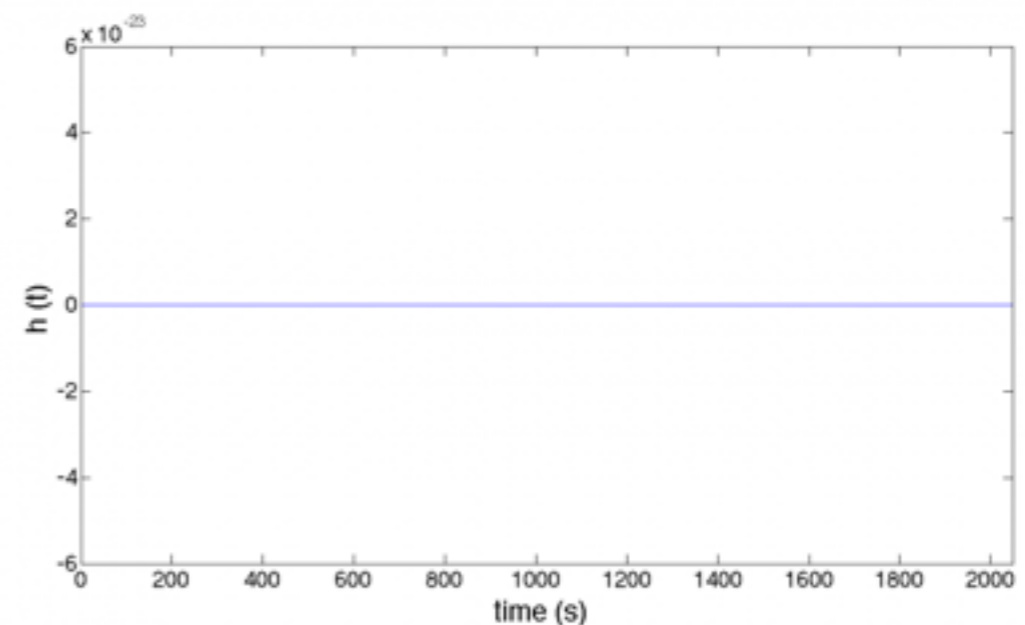
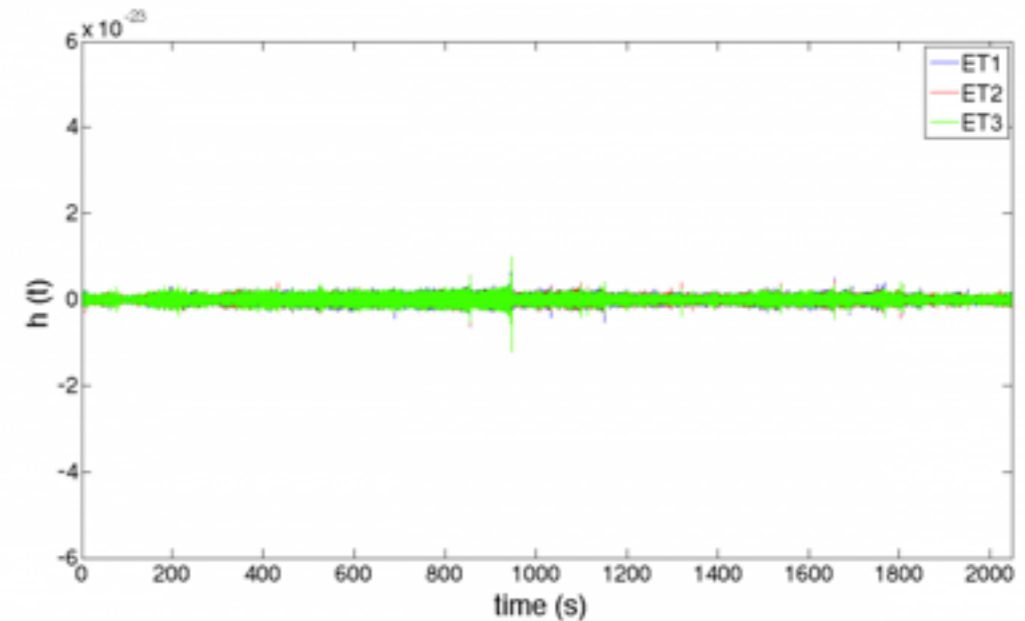


Comparing recovered redshift distribution with first MDC



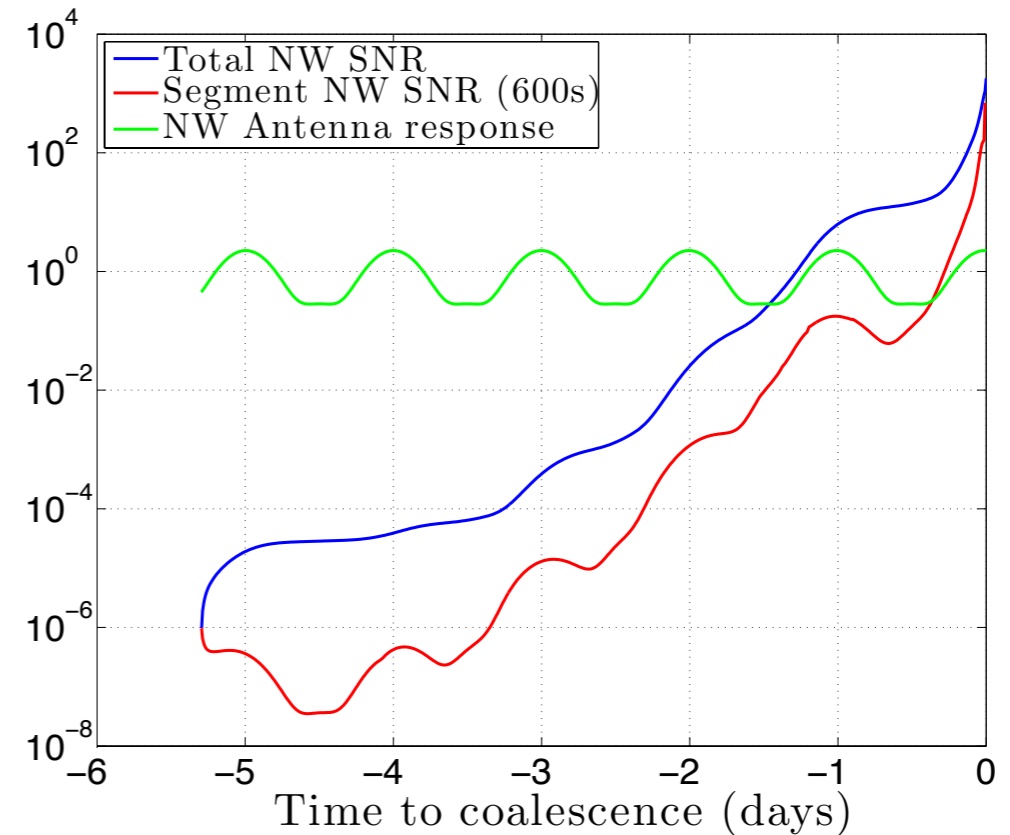
Null stream

- Can construct the null stream using MDC data.
- A theoretical null stream location has been added in lalsuite and gstlal.
- Need to determine how to apply it.
- This should be done in conjunction with the testing of glitchy data as this will affect how the null stream behaves.



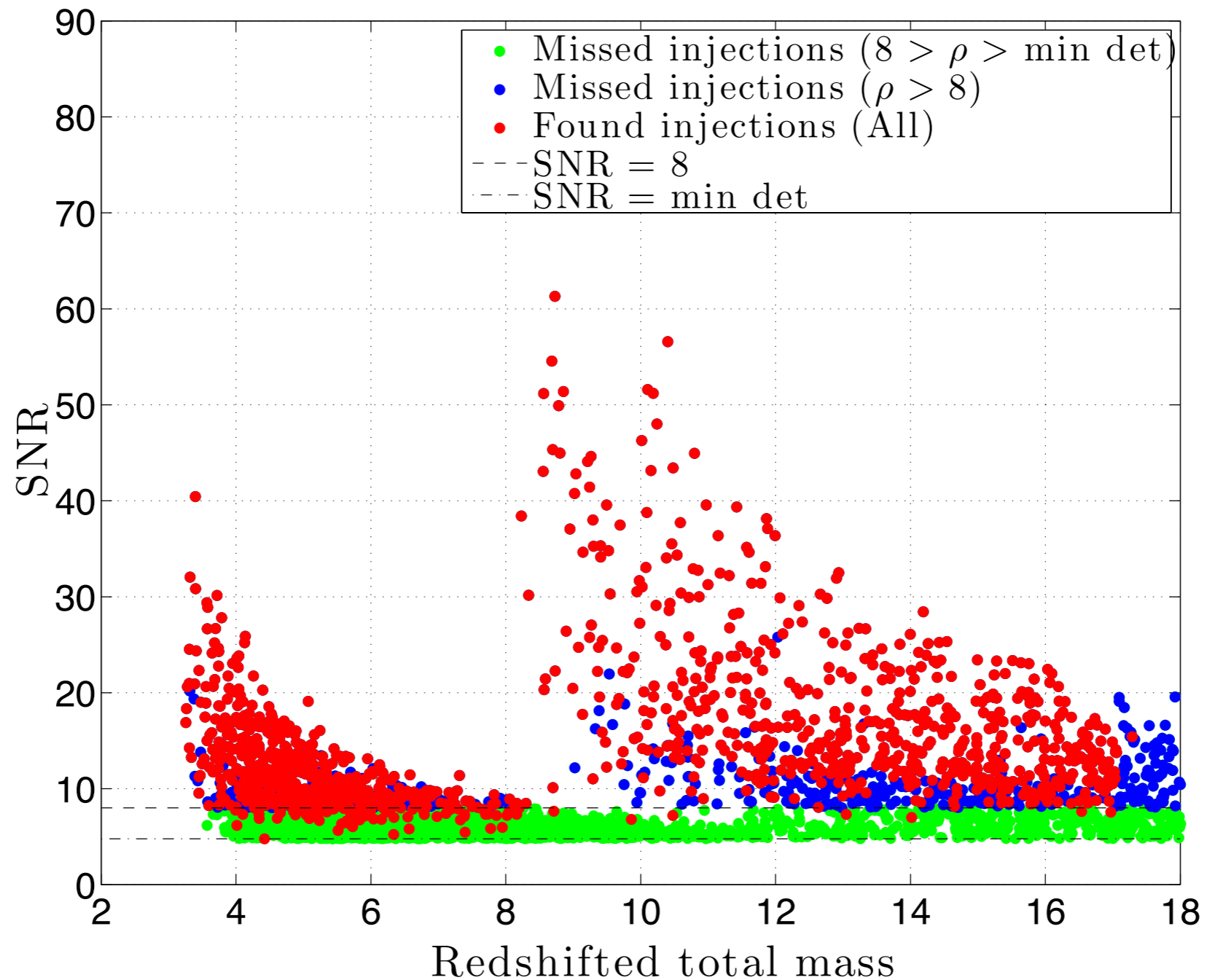
SNR time series

- gstlal begins tracking events with a single detector SNR > 4 .
- This is stored internally as an SNR time series.
- Being able to output this and apply it to low frequencies could prove very useful, i.e. the early detection of inspiral signals.

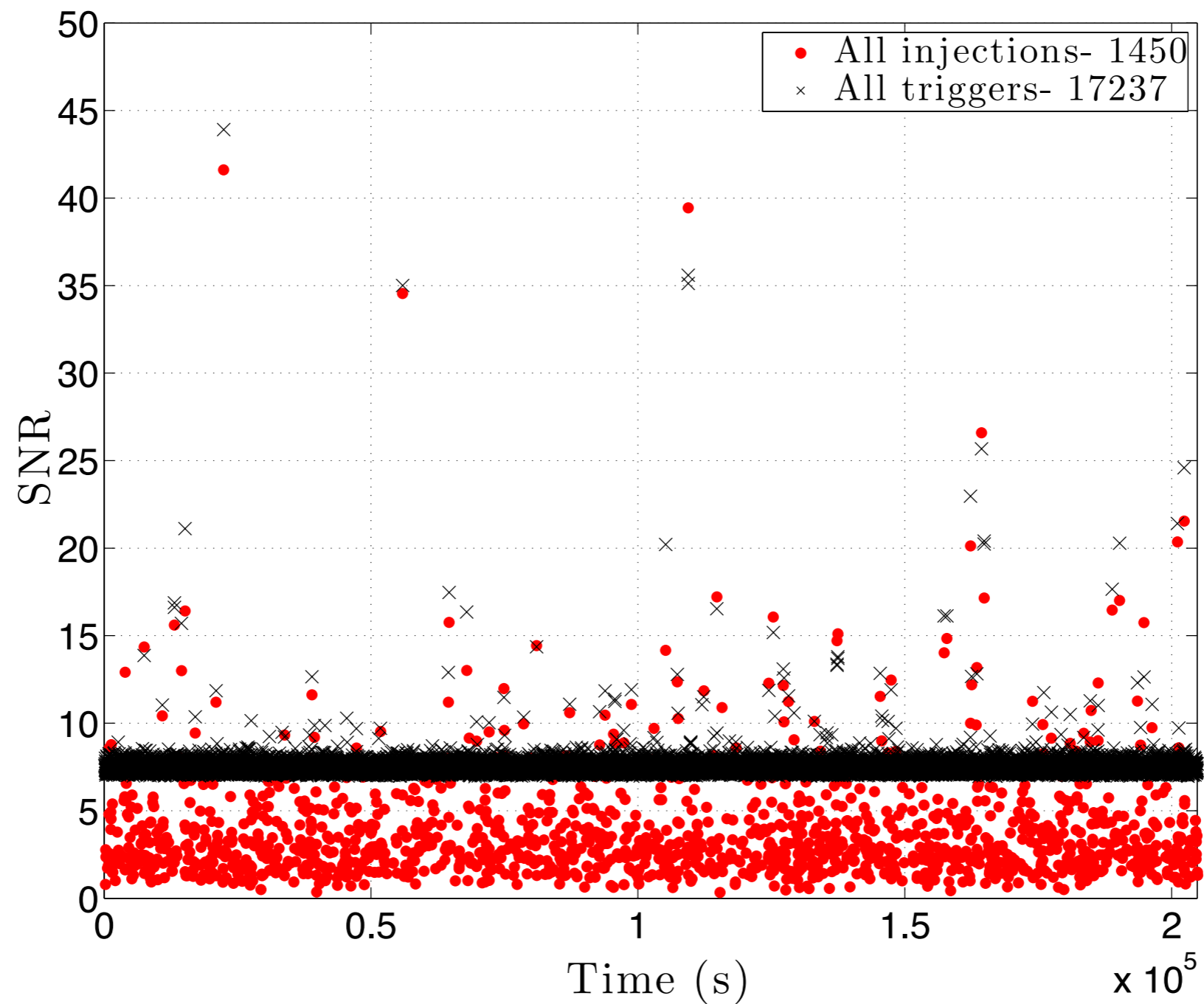


BNS + BBH

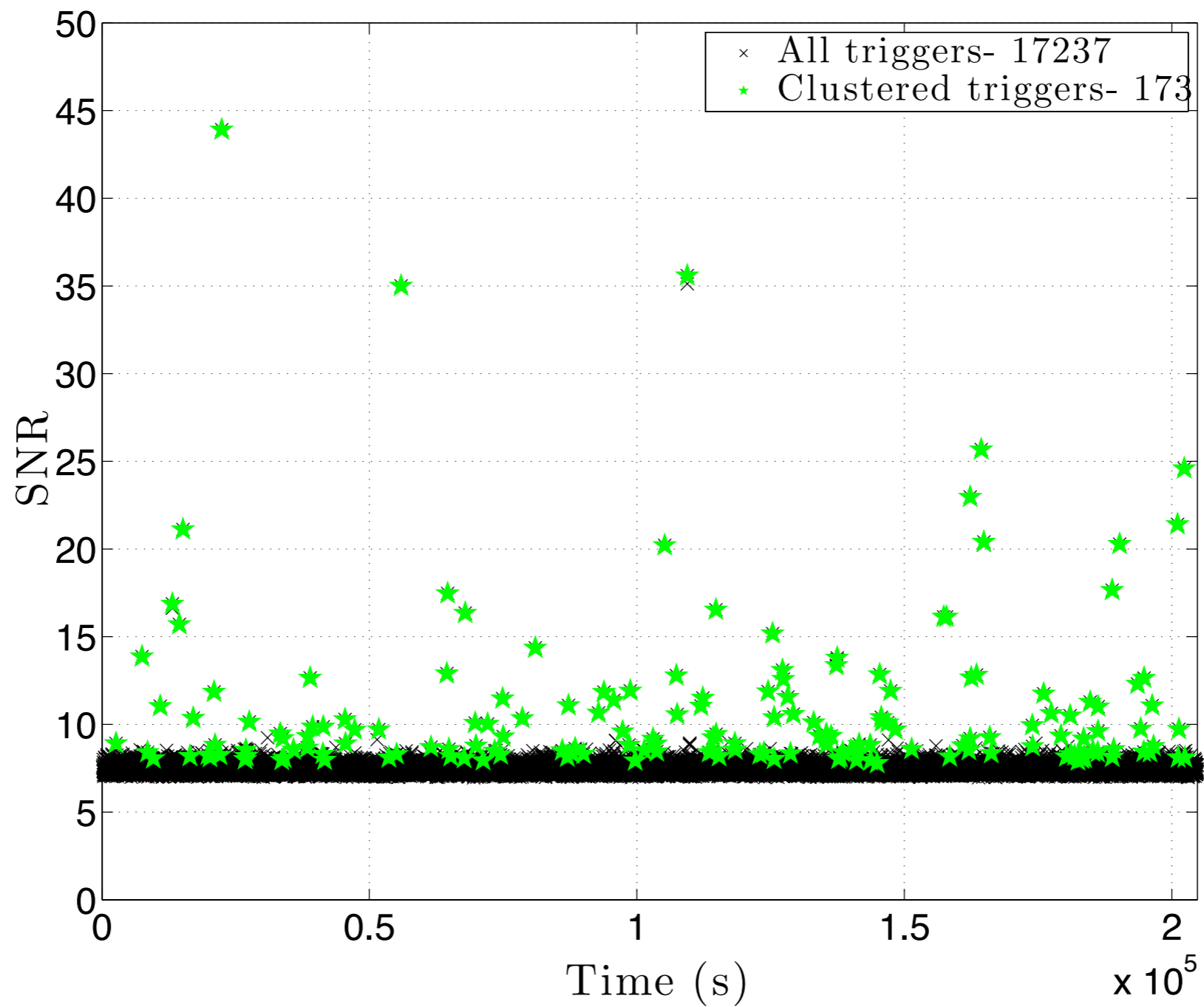
Missed/Found



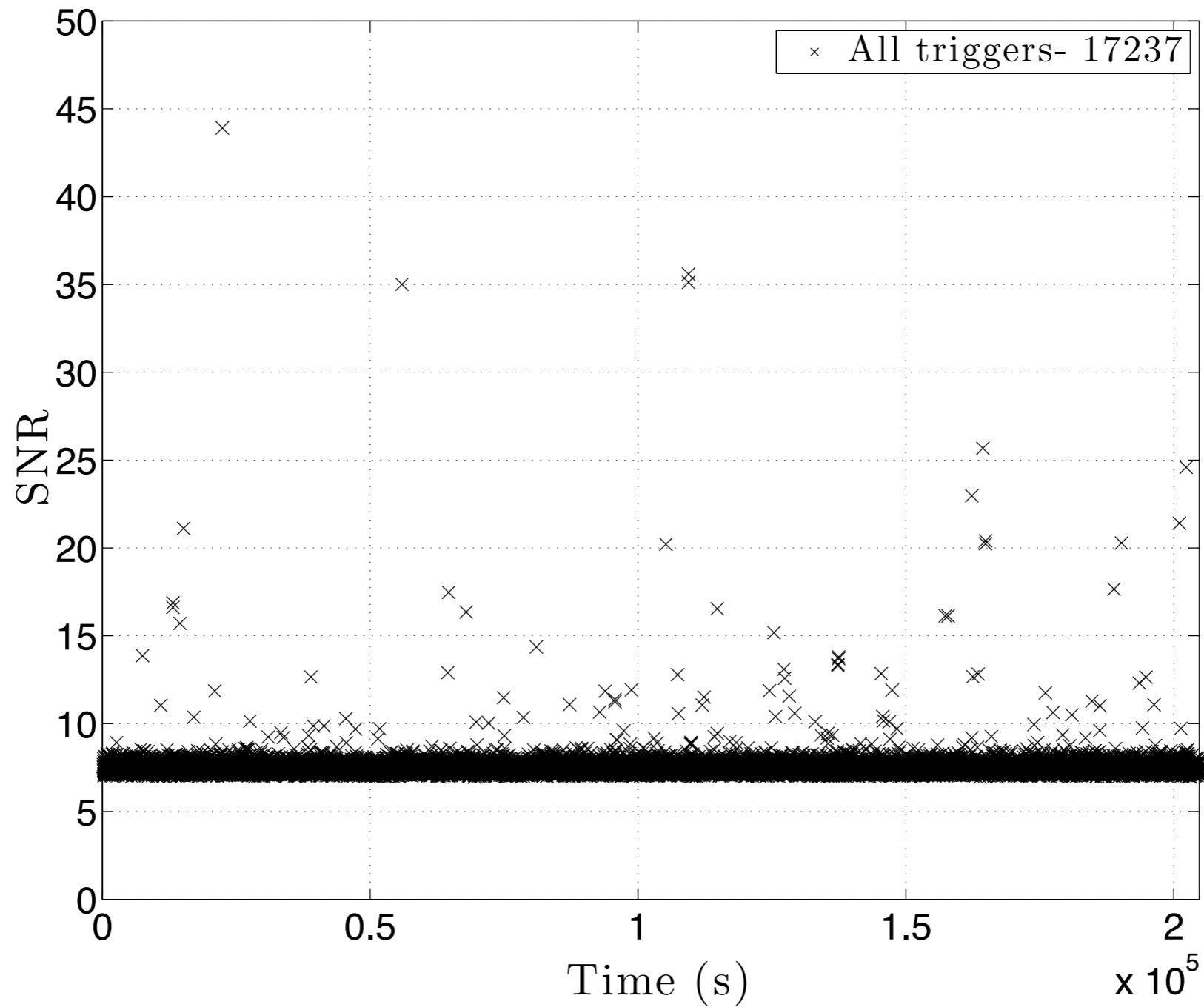
Running the analysis: Injections + triggers



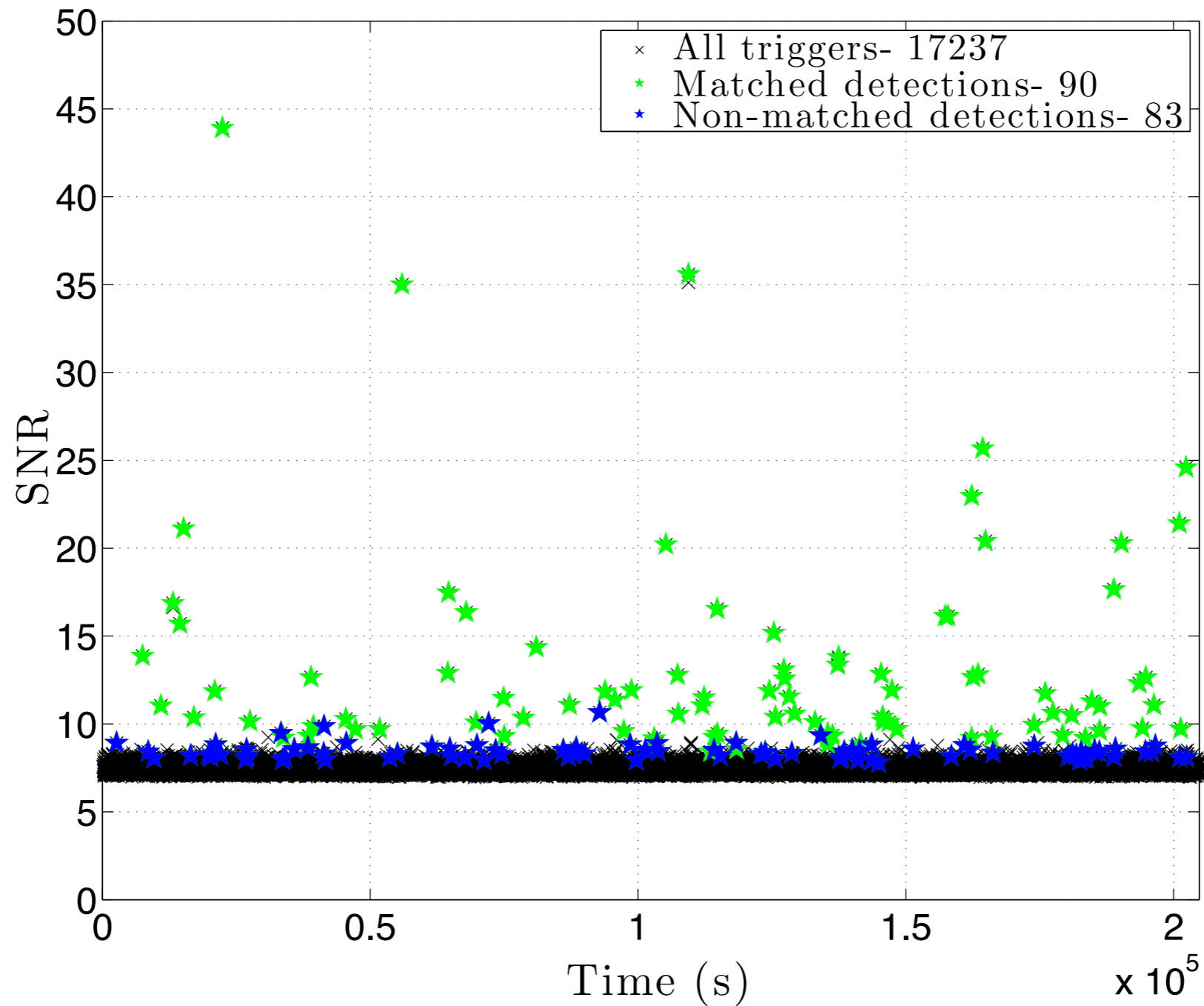
Running the analysis: Clustered triggers



Running the analysis: Triggers

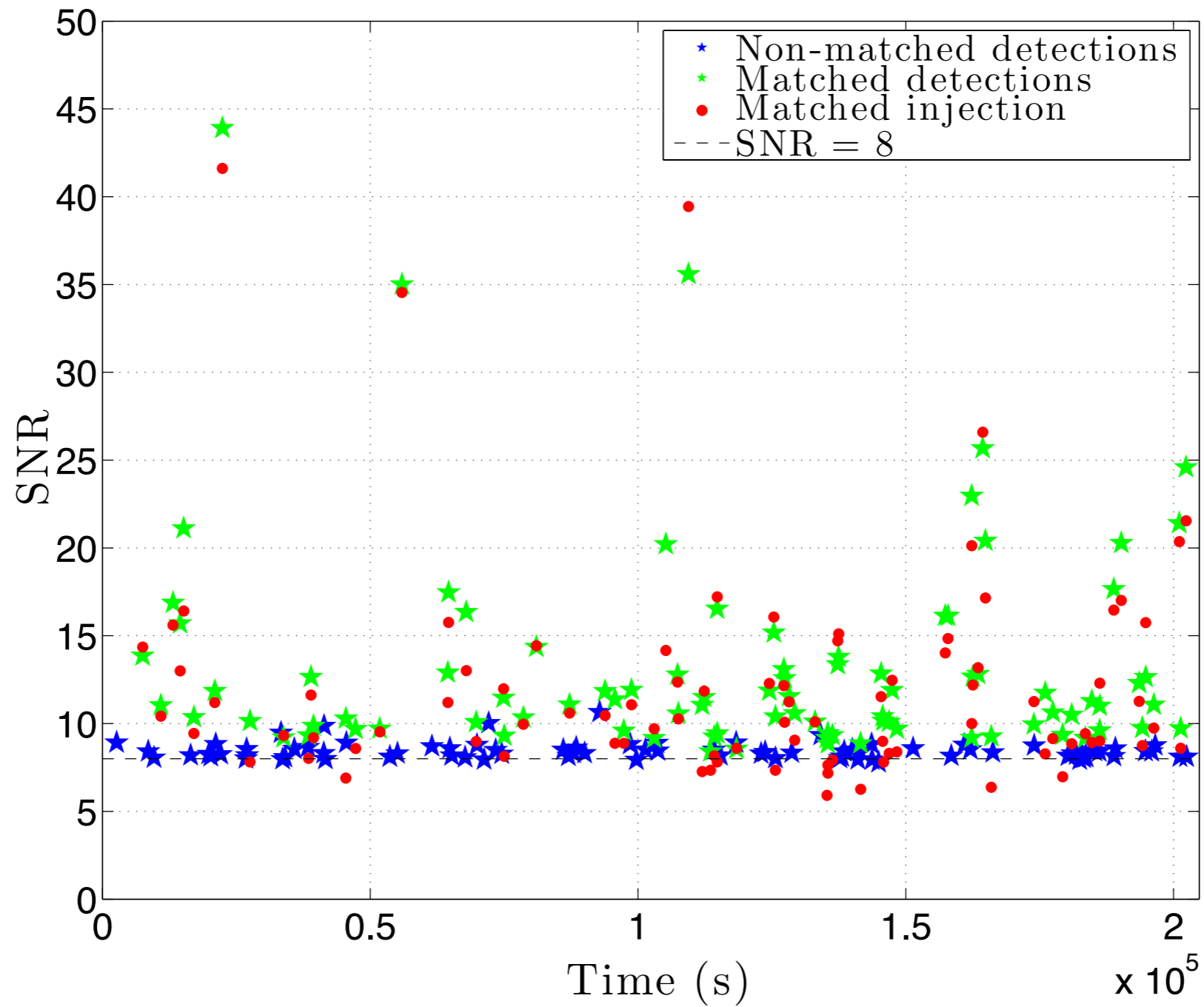


Running the analysis: Matched/Non-matched



Time-SNR

Matched/Non-matched



Detector locations

