S4 H1H2 Coherence

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I have writen a set of scripts and routines in tcl and matlab that can be used for calculating the long-term coherences and transfer functions. The main idea is:

1. The user makes a parameter file specifying the two channels to be analyzed, the GPS start and end times for the calculation (which can be all of S4, for example), the resolution (e.g. 0.1 Hz) etc.

2. The user then runs a script on the ldas-grid, which automatically figures out which jobs should be done, submits them to condor and handles the output.

The main advantage of this code is that a lot of data can be analyzed very quickly - for example, all of S4 between two RDS_L1 channels can be done in about 1 hour, depending on how busy the cluster is. This code may be useful in looking at correlations of various channels with AS_Q, for H1-H2 correlations, or for inter-site PEM-PEM correlations.

Some details:

- The code uses the routines used in the stochastic search for loading the data.
- The useful data segments are obtained using segwizard (once only!).
- The main (tcl) script determines which of these segments should be analyzed, depending on the GPS start and end times in the parameter file.

- For each segment, the data is split into chunks of length T, where T=1/resolution, as specified in the parameter file (so for 0.1 Hz resolution, we use 10 sec chunks).

- For each chunk, a compiled matlab routine calculates the PSD's for both channels, and the CSD. It then sums over the chunks in the given segment, and saves the results (and the number of chunks) in a file specific to the segment. Built-in matlab routines are used for PSD and CSD calculations.

- When all segments are analyzed, another compiled matlab routine is called, which loads the segment-specific files and averages the spectra. It also calculates the transfer function of channel 1 to channel 2 and their coherence ($\gamma^2 = |CSD|^2/PSD1/PSD2$).

- I have verified that the results agree with DTT and with the built-in matlab routines using shorter data segments.

I ran the code to calculate the coherence between AS_Q channels of H1 and H2 for all of S4 data, with v04 data quality flags. The results are shown in the following plots. In the following, we estimate the variance of the coherence to be:

$$\sigma^2_{\gamma^2} = 2\gamma^2(1-\gamma^2)^2/N, \tag{1}$$

where N is the number of averages (the total number of chunks over the whole analysis time). For this analysis, I used 0.1 Hz resolution, and I averaged 103,000 10-sec chunks (i.e. $N = 103000$). First, Figure 1 shows the overall coherence. Note that there is a bump around 100 Hz which does not exist in the study by F. Raab and J. Betzwieser (LHO ilog from Mar 18 2005).

I averaged γ^2 and σ_{γ^2} over the 65-100 Hz band for each of the 895 segments and plotted their ratio in Figure 2. This Figure shows that there are 9 outlier jobs:

- 793394460 - 793397020 - There are glitches in H2 in the last 3 seconds of the last 10-sec chunk. Ending the segment at 793397010 would avoid the problem. See Figure 3. The ilog entries mention seismic events and/or glitches in H2 FMY optical lever.

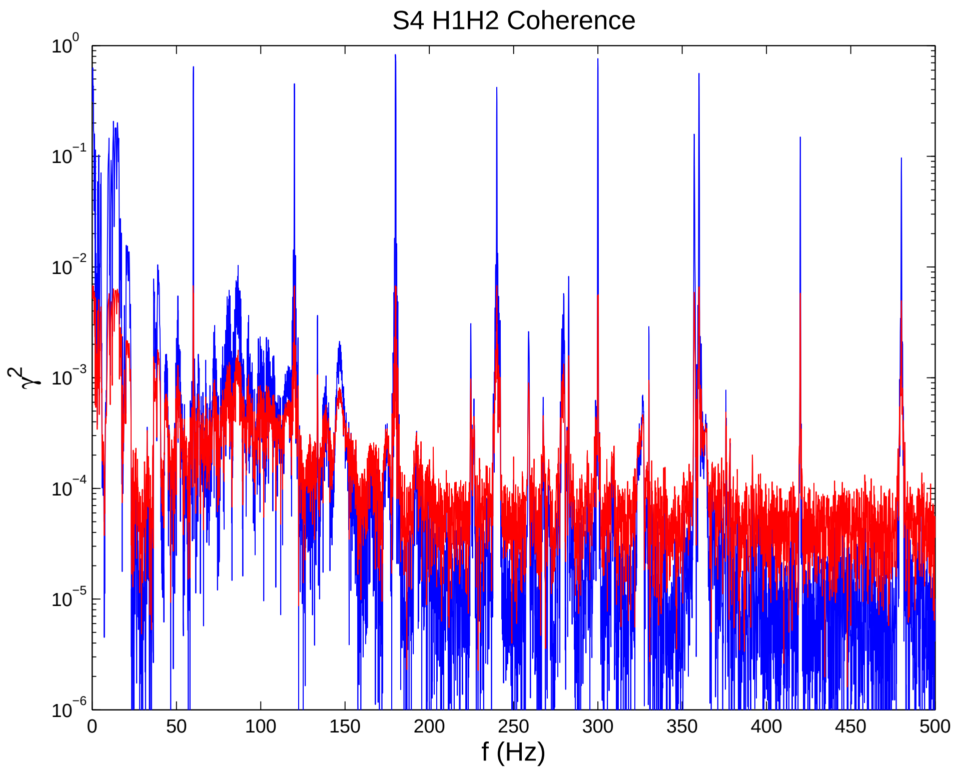


Figure 1: The coherence is plotted vs frequency in blue, and $4\sigma_{\gamma^2}$ is in red.

- 793603778 - 793609138 - As above, there is a glitch in H2 3 sec into the last 10-sec chunk. Ending the segment at 793609128 would avoid the problem. The ilog entries mention seismic events and/or glitches in H2 FMY optical lever.

- 793927065 - 793928835 - As above, there is a glitch in H2 2 sec into the last 10-sec chunk. Ending the segment at 793928825 would avoid the problem. The ilog entries mention seismic events and/or glitches in H2 FMY optical lever.

- 794039700 - 794042968 - As shown in Figure 4, several 10-sec chunks stand out, scattered throughout this job. Again, one can observe glitches in H2. One may have to make several cuts to avoid the problem. On the other hand, the effect is not very large. The ilog entries mention seismic events and/or glitches in H2 FMY optical lever.

- 794063215 - 794063604 - The last two 10-sec chunks stand out. Ending the segment at 794063575 would avoid the problem. But, the effect is small, could not observe it in the time-series. The ilog entries mention seismic events and/or glitches in H2 FMY optical lever.

- 794073182 - 794074543 - The last 10-sec chunk stands out. Ending the segment at 794074532 would avoid the problem, but, again, the effect is very small. The ilog entries mention seismic events and/or glitches in H2 FMY optical lever.

- 794254464 - 794255211 - Out of 74 10-sec chunks in this job, chunk 61 stands out the most (see Figure 5). However, the effect is very small, it could not be observed in the time-series. The ilog shows that there was a fork-lift operation during this job that eventually caused both IFOs to lose lock.

- 794623198 - 794626785 - This job takes place during hardware injections.

- 794626788 - 794629420 - This job takes place during hardware injections.

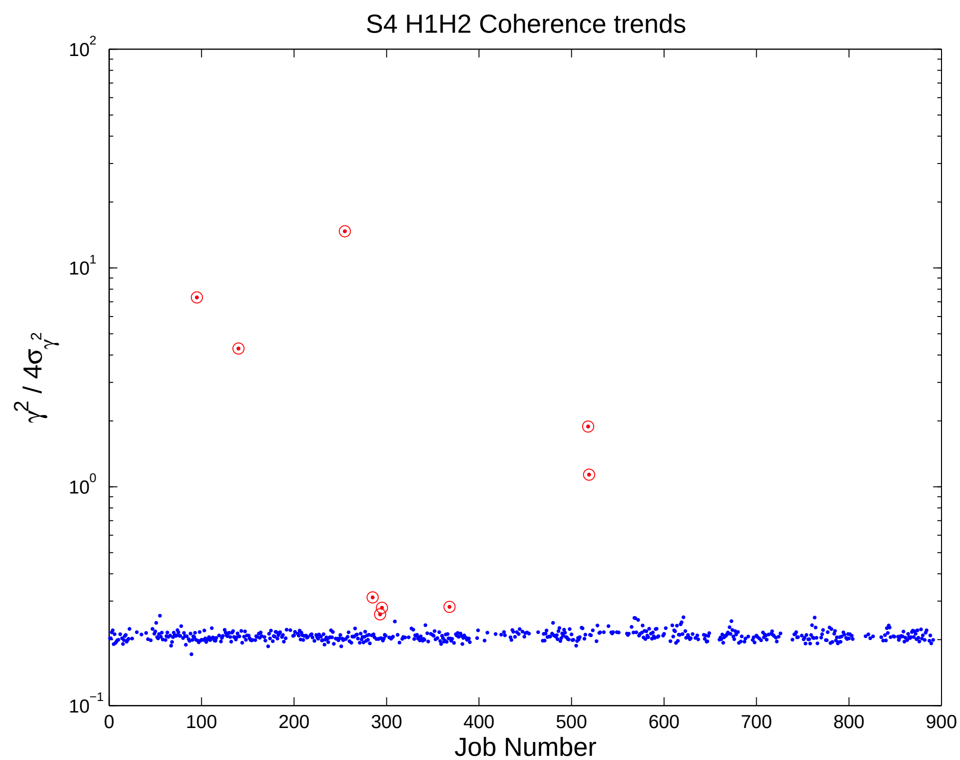


Figure 2: $\gamma^2/4\sigma_{\gamma^2}$ as a function of segment number. Note the outliers shown in red.

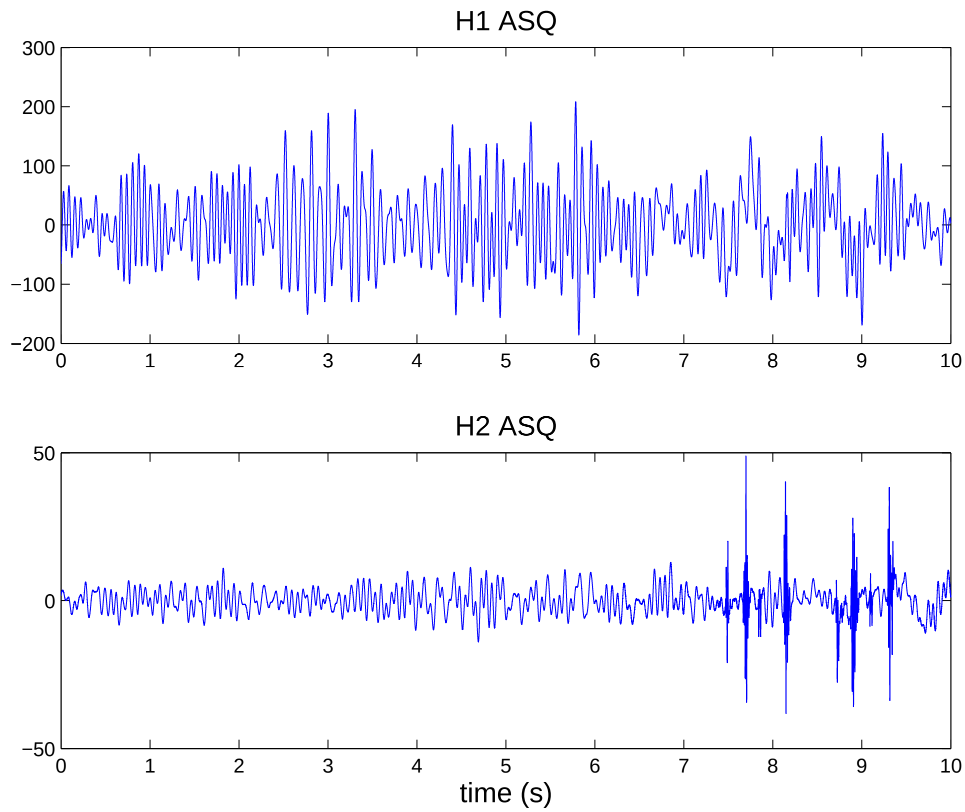


Figure 3: Time traces showing glitches in H2.

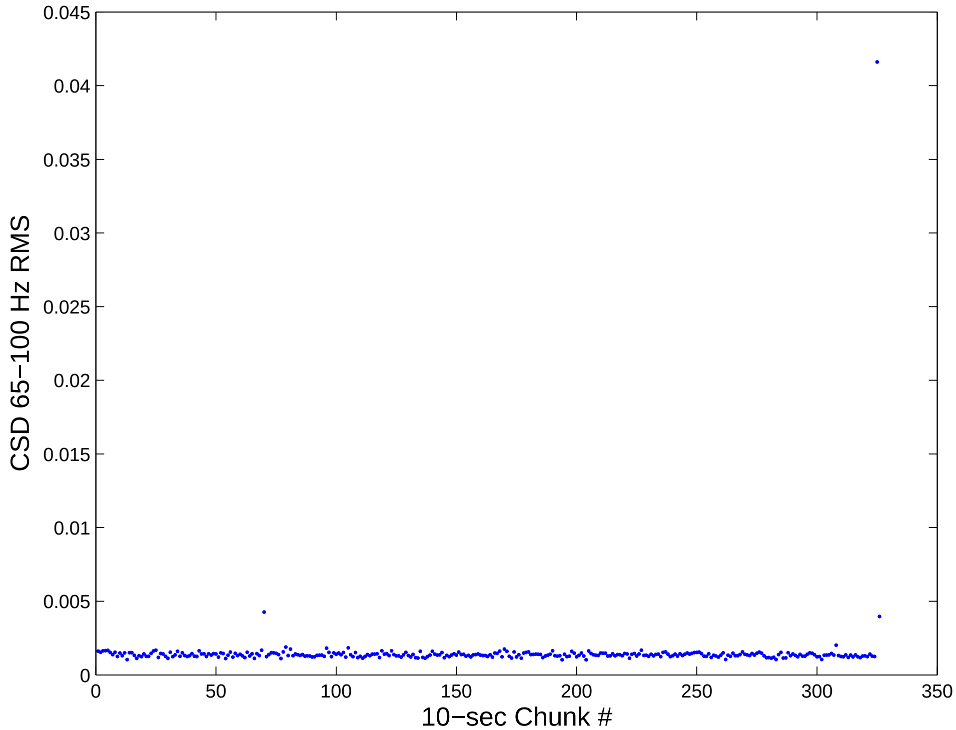


Figure 4: The CSD RMS trend in the 65-100 Hz band for the job 794039700 - 794042968. Each point corresponds to a 10-sec period.

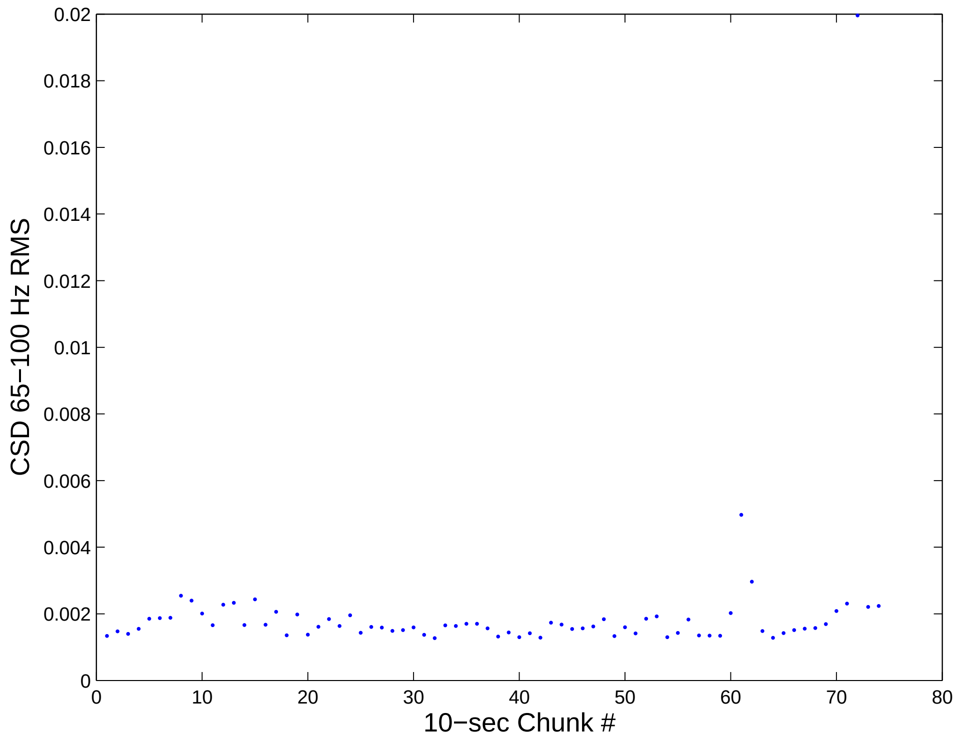


Figure 5: The CSD RMS trend in the 65-100 Hz band for the job 794254464 - 794255211. Each point corresponds to a 10-sec period.

Figure 6 shows the overall coherence after removing these outliers. Figure 7 shows the coherence as calculated in 10 equally long chunks of S4 data (each about 30 hours long). Figure 8 shows the corresponding power spectra. Note that the bump is gone and the coherence seems relatively stable over the course of the run. Finally, note that besides the 60 Hz harmonics, we observe structure also at 107.9, 133.7, 224.6, 258.9, $\sim$ 279, 282.7, 330.2 Hz etc.

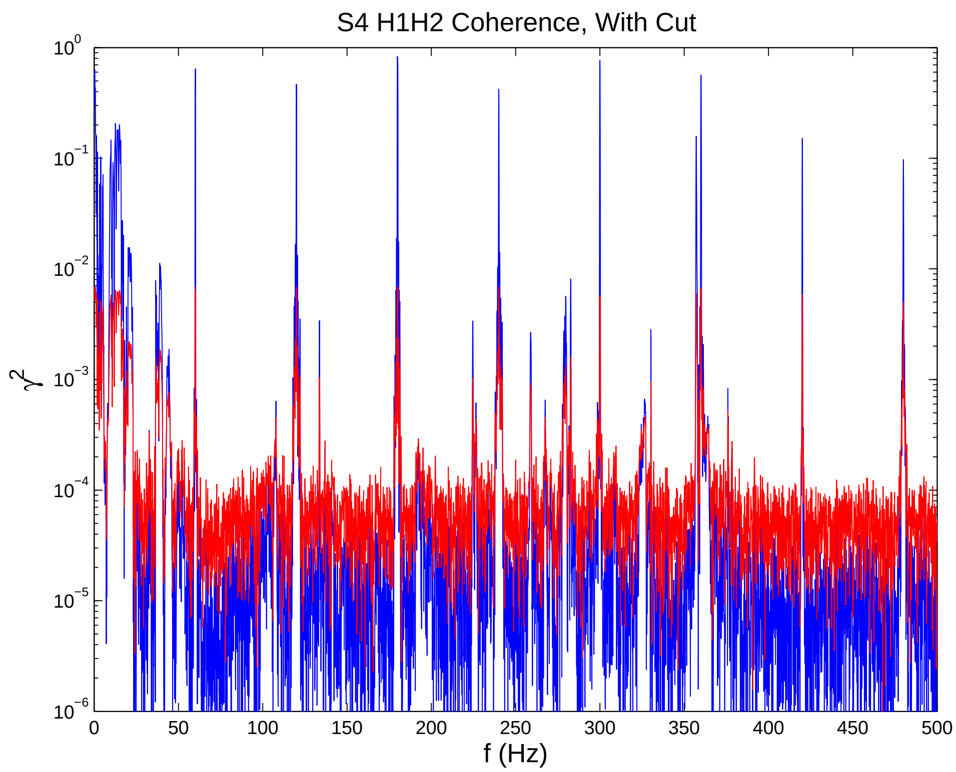


Figure 6: The coherence is plotted vs frequency in blue, and $4\sigma_{\gamma^2}$ is in red. The 9 outliers have been removed from the calculation.

Figure 9 shows the histogram of γ - note the deviation from the expected exponential behavior at large values of γ. Figure 10 shows the improvement if we remove the outlier jobs, ignore frequencies below 50 Hz, and ignore the 60 Hz harmonics. The behavior is more exponential-like, although the remaining structure causes a smaller non-exponential tail at large γ values.

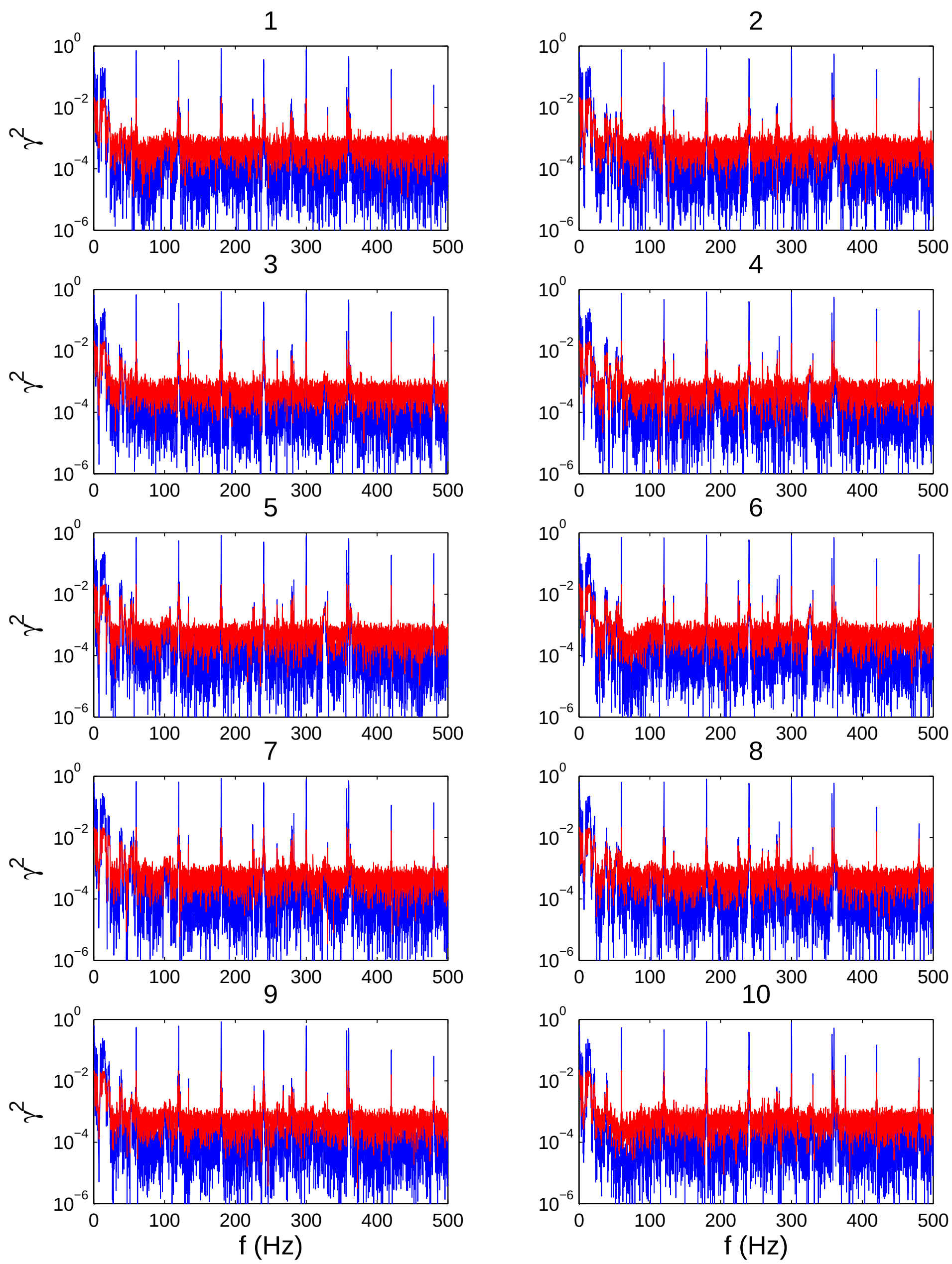


Figure 7: Same as the previous figure, but the data is split into 10 periods of about 30 hours.

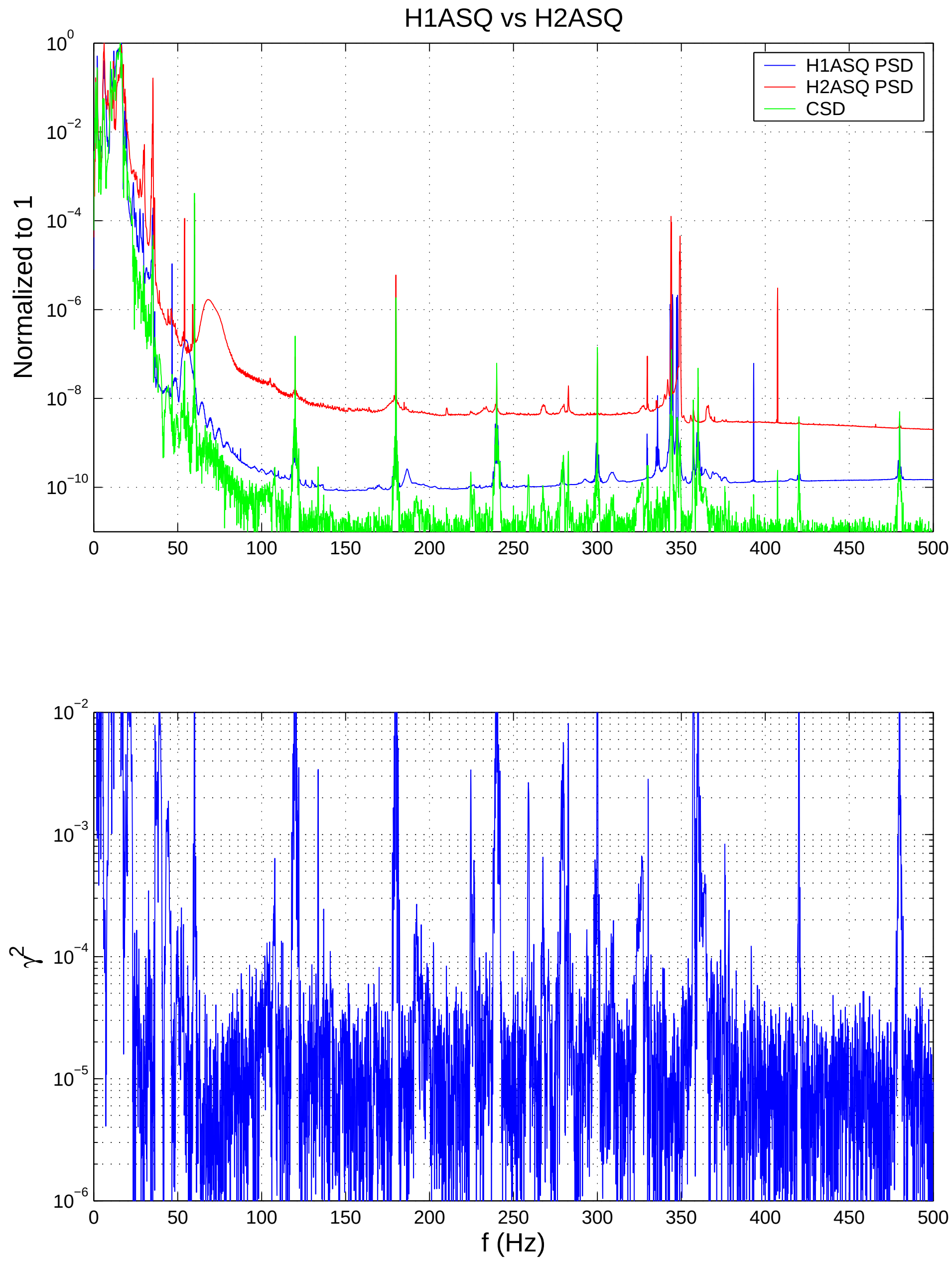


Figure 8: Power spectra and coherence.

Note also that some of the remaining peaks are due to the injected pulsars. Finally, Figure 11 shows the coherence (and σ_{γ^2}) split into finer frequency bins.

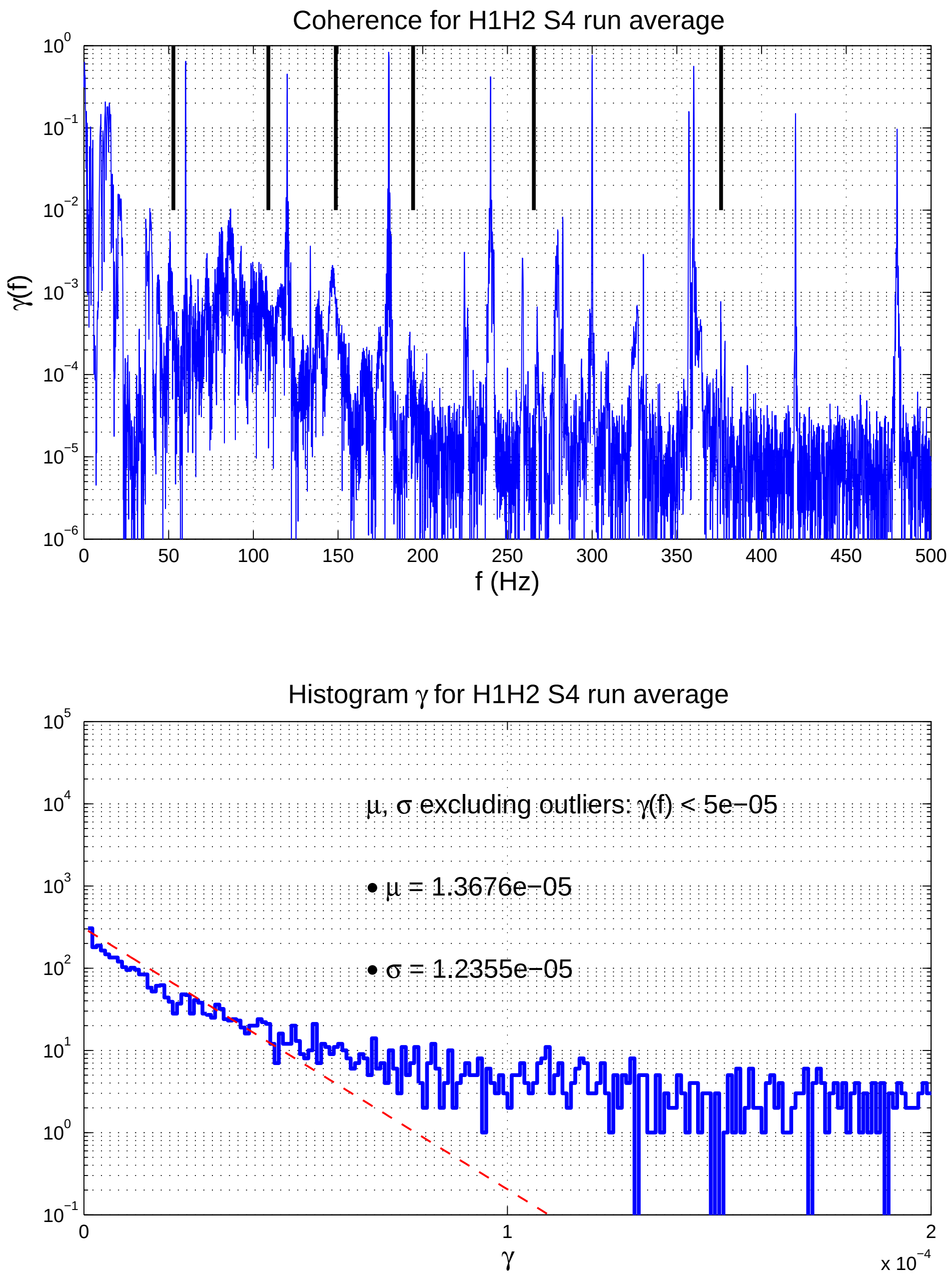
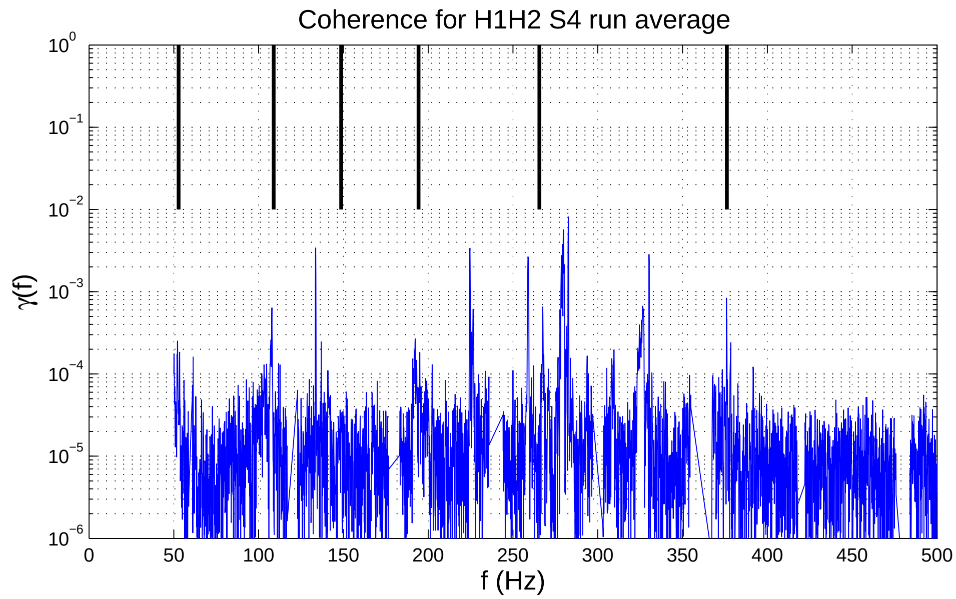


Figure 9: Top: Coherence vs frequency (including outliers). The black lines denote positions of pulsar injections. Bottom: Histogram of the coherence - note that it follows the expected exponential behavior at low γ values, but that it deviates from the exponential at large gamma values.



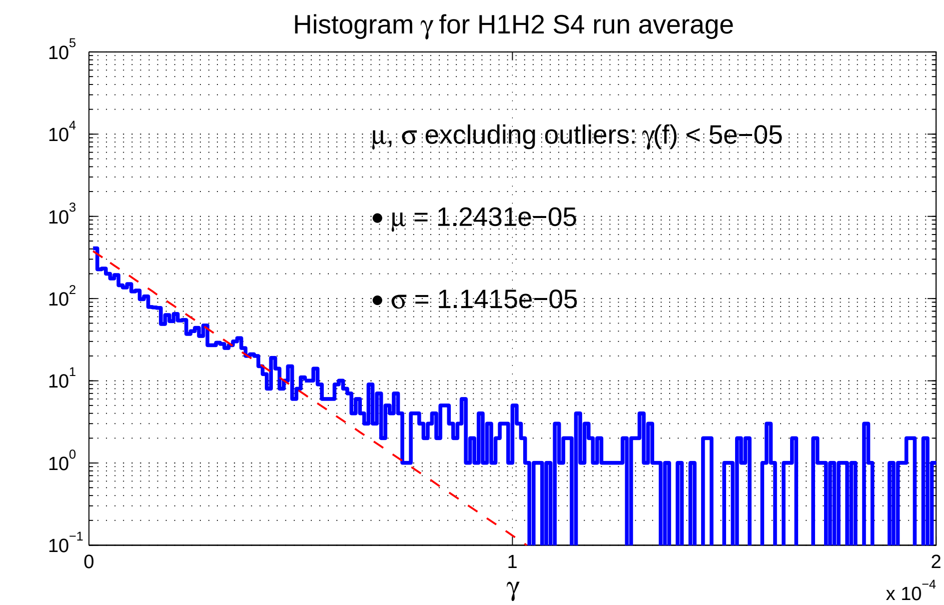


Figure 10: Same as above, but we remove the outlier jobs, the frequencies below 50 Hz, and the 60 Hz harmonics.

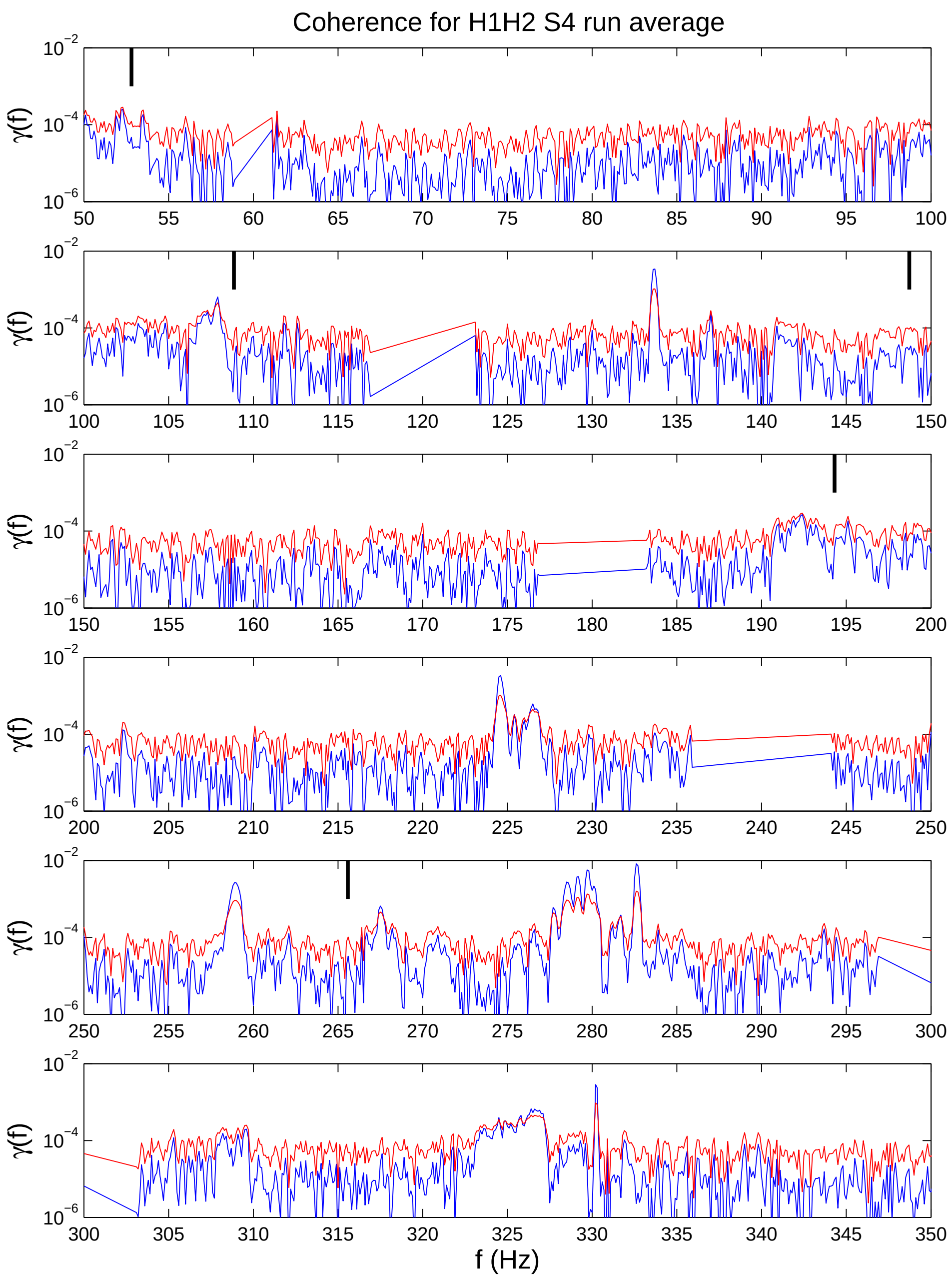


Figure 11: Coherence (in blue) and σ_{γ^2} (in red) are shown in finer frequency bins.