LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Technical Note	**LIGO-T050082-00-D**	2005/05/20
Coherence Between LLO and LHO		
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This is an internal working
note of the LIGO project

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This note discusses inter-site correlations. The analysis was done using the tfcoh package for calculating the long-term coherence between two channels. Four channel pairs were studied. The variance on coherence is estimated by:

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

where N is the number of averages. In this analysis, 117712 10-sec segments were used, yielding 0.1 Hz resolution - the only exception is the H1ASQ-L1ASQ pair, where a number of processes failed (memory allocation requests failed) so we had only 81923 chunks.

1 H1:LSC-AS_Q vs L1:LSC-AS_Q

Figure 1 shows the coherence between the two AS_Q channels, and Figure 2 also shows the power spectra. The coherence seems fairly clean, although we observe two features - the dip around 50 Hz and the only obvious line (apart from 60 Hz) at 376 Hz. When splitting the run into 10 intervals of equal length (see Figure 3), we observe no surprizes except that the 376 Hz line appears only in the last interval. If we plot the line amplitude as a function of the job number (see Figure 4), we observe it only in a hand-full of jobs at the end of the run. Checking against the ILOGs, we find that a strong (binary system) pulsar hardware injection was turned on at the end of the run - the times are consistent with the outlier jobs in the Figure 4.

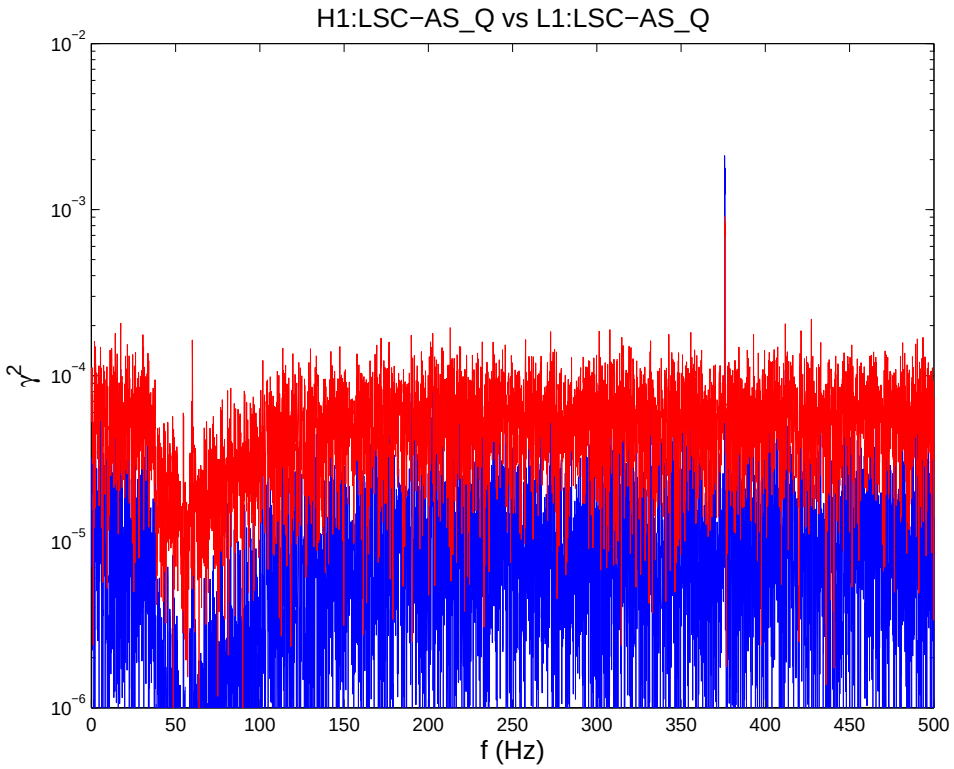

Figure 1: Coherence over all of S4 is shown in blue, $4\sigma_{\gamma^2}$ is shown in red.

1.1 50 Hz Dip

Figure 5 shows the trend of the 40-55 Hz bin. Note that there is a number of discrete steps in this trend. We examine some of them more closely. See Figure 6 for more detail.

- Job 120: H1 ASQ has the last two 10-sec segments bad: 793712588-601.
- Job 404: H1 ASQ has several bad 10-sec segments: 794611646-656, 794612416-456, 794612556-566, 794612636-646. ILOG notes winds and H2 losing lock around this time.
- Job 466: L1 ASQ has several bad 10-sec segments: 794907679-789, 794908019-029. ILOG notes a small train.
- Job 467: L1 ASQ has several bad 10-sec segments: 794911217-377, 794911537-747, 794911947-2037. ILOG notes a train.
- Job 473: L1 ASQ has several bad 10-sec segments: 794925247-257, 794925327-337, 794925467-677. ILOG notes a train.
- Job 474: L1 ASQ has several bad 10-sec segments: 794925758-978. ILOG notes a train.

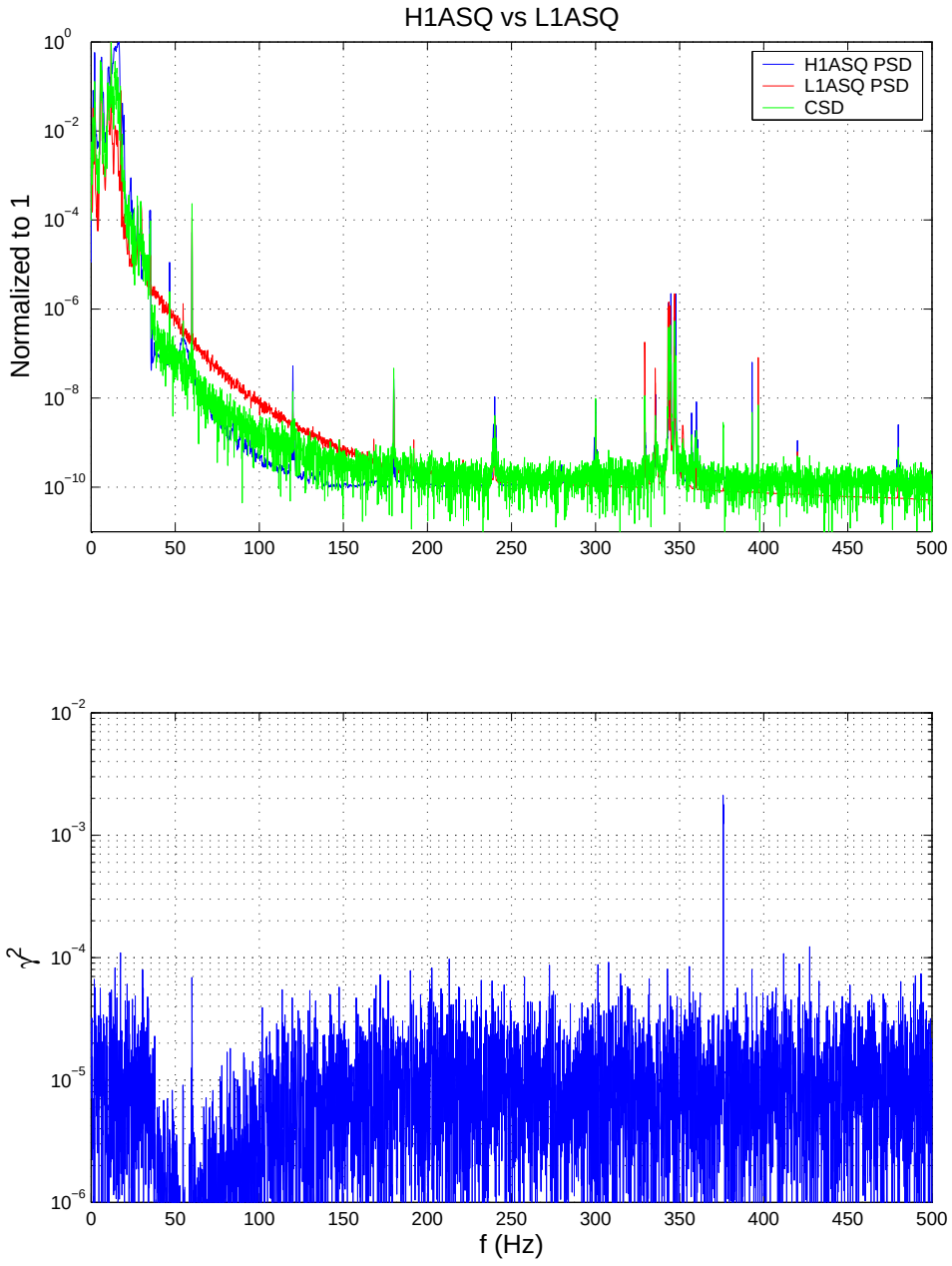

Figure 2: Power spectra and coherence

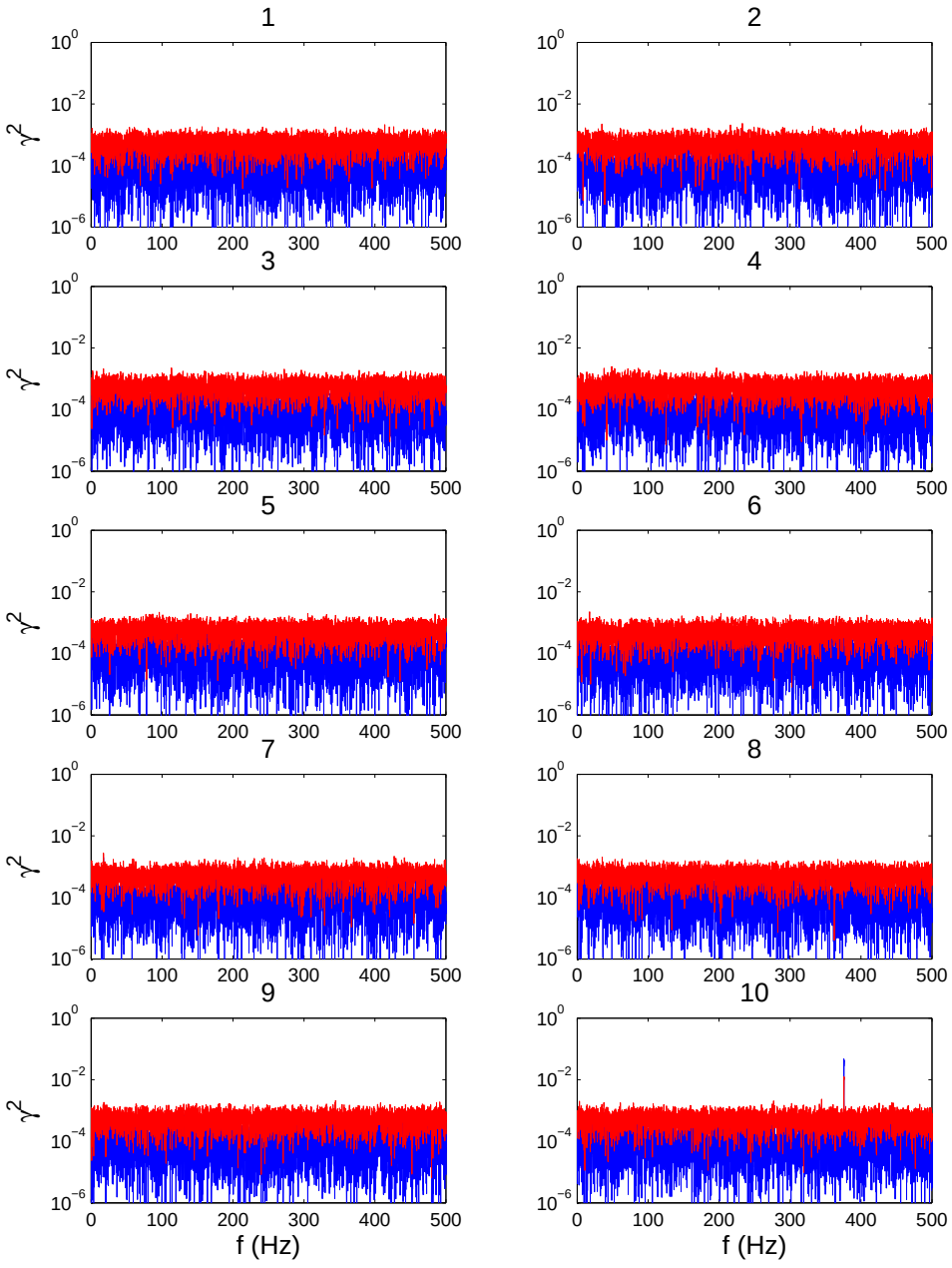

Figure 3: Coherence for 10 intervals of roughly equal length is shown in blue, $4\sigma_{\gamma^2}$ is shown in red.

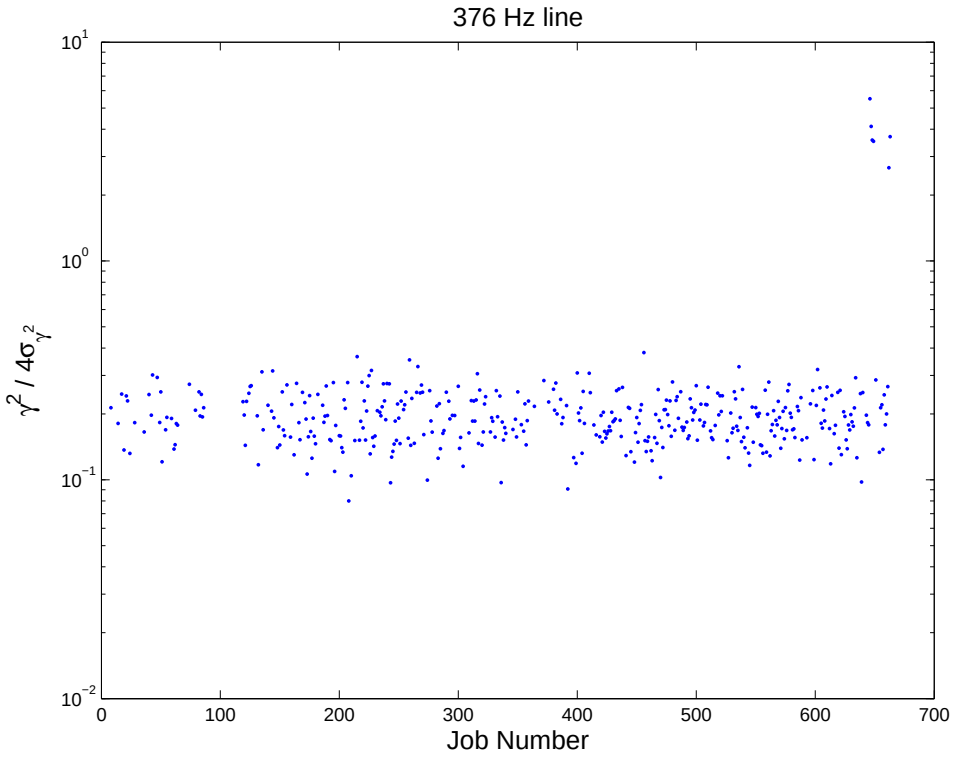

Figure 4: Trend of $\gamma^2/4\sigma_{\gamma^2}$ for the 376 Hz line. Each point corresponds to one job.

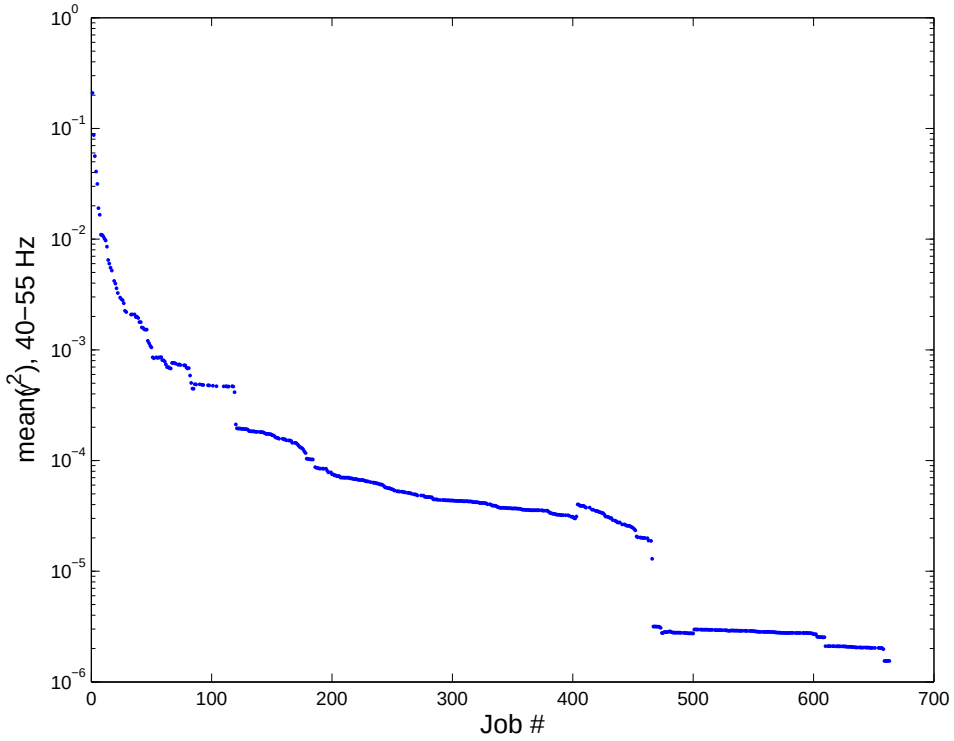

Figure 5: Coherence trend in the 40-55 Hz bin.

- Job 610: H1 ASQ has one bad 10-sec segment: 795459217-227. ILOG notes some seismic events.
- Job 659: H1 ASQ has the last two 10-sec segments bad: 795652378-398. ILOG notes wind and seismic events.

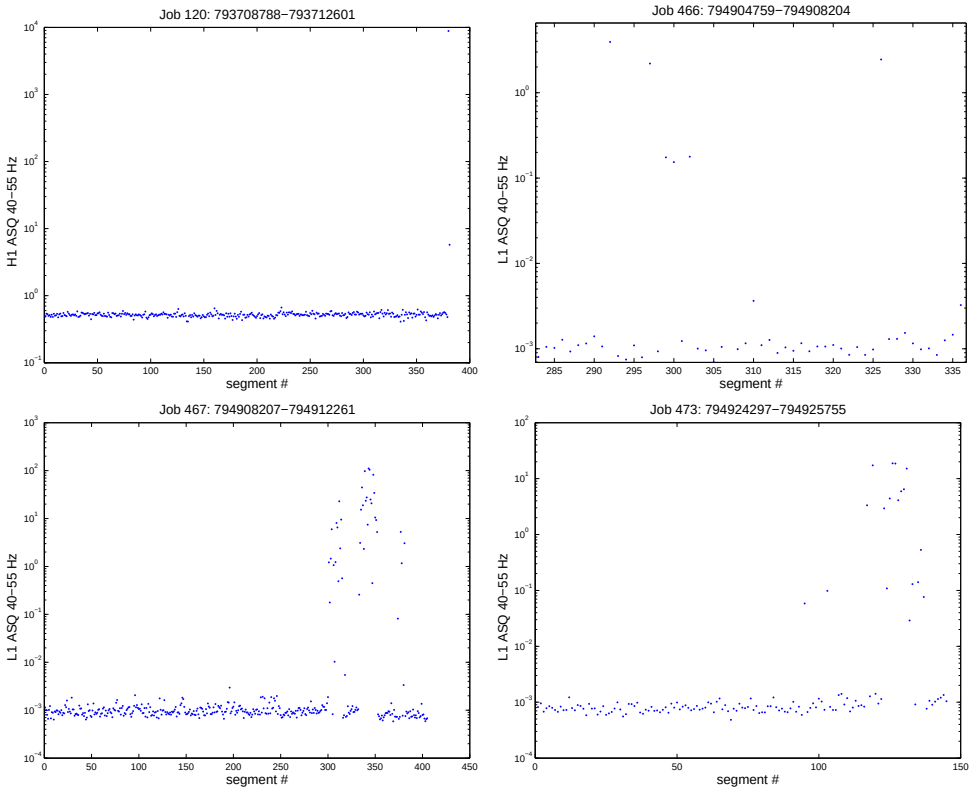

Figure 6: Trends in the 40-55 Hz bin, for the suspect jobs.

Figure 7 shows the trend (over all jobs) in the 40-55 Hz band when the suspect jobs are ignored - the trend is much smoother, and similar to a good band (250-300 Hz) but there still seem to be small discontinuities. Figure 8 shows the coherence when ignoring the suspect jobs - note that the dip is nearly gone.

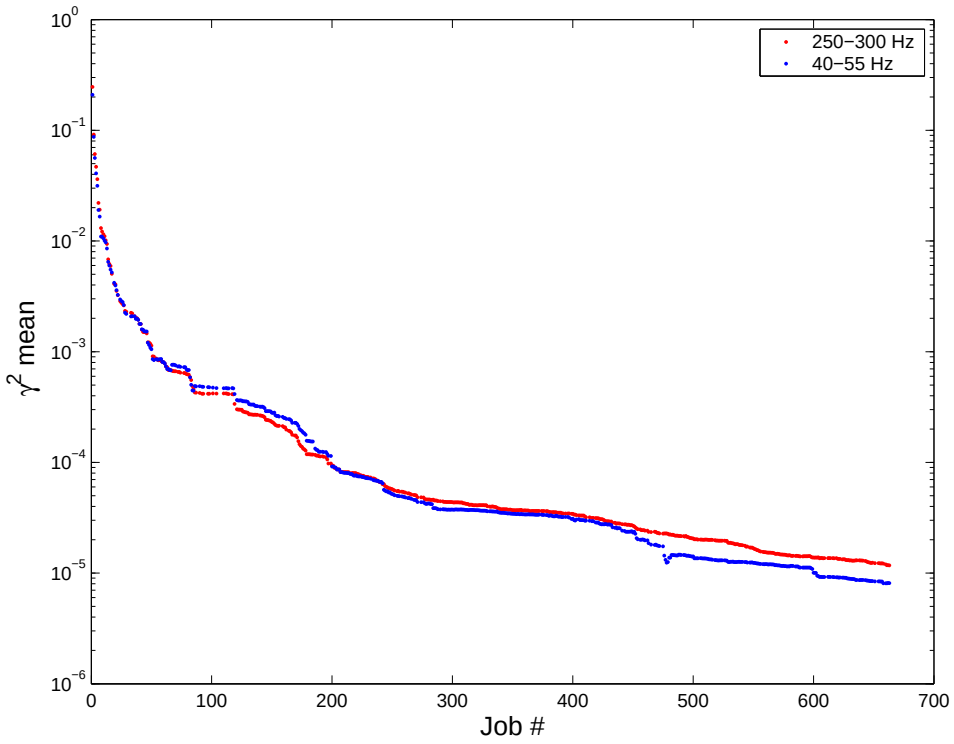

Figure 7: Trends in the 40-55 Hz and in the 250-300 Hz band, without the suspect jobs.

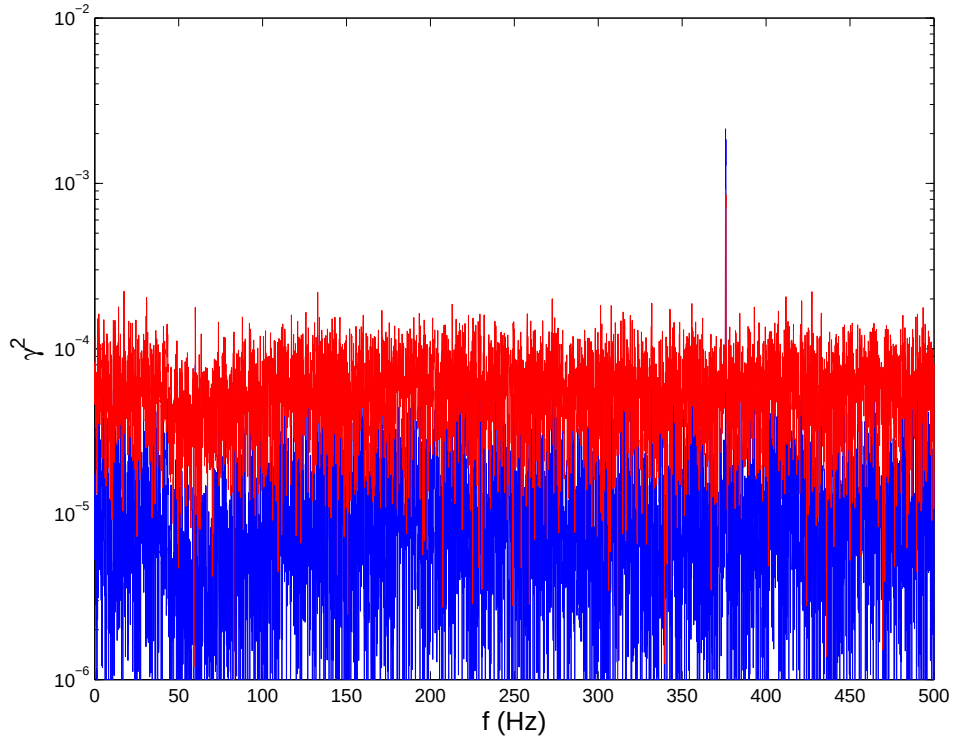

Figure 8: Coherence over all of S4 when ignoring the suspect jobs - note that the dip is nearly gone.

2 H1:LSC-AS_Q vs L0:PEM-COIL_MAGX

We now study the coherence of the H1ASQ channel and the magnetometer channel at LLO. This channel was suggested by Robert Schofield as the most sensitive to the magnetic sources.

Figure 9 shows the coherence between the two channels over all of S4 and Figure 10 shows the corresponding power spectra. We observe some of the 60 Hz harmonics and some of the 100 Hz harmonics (expected by R. Schofield due to data-logging). If we zoom in on one of these peaks (see Figure 11), we observe the 1 Hz harmonic side-bands - these side-bands are also observable in the PSDs of both channels, even using DTT. Note also the line at 393 Hz, which happens to be the frequency of one of the calibration lines in H1 ASQ - this line also appears significant.

Figure 12 shows the coherence in 10 intervals of equal length. One can observe some fluctuation over time in these peaks. To get a better picture of these fluctuations, we plot the amplitude of various peaks as a function of the job number in the Figure 13. Note that the 393 Hz line fluctuates very much, while the 100, 180, and 200 Hz lines seem to smoothly plateau toward the end of S4 - there are a few discrete steps that tend to happen at some of the jobs discussed in Section 1.1. We also include the trend of 130-170 Hz band, indicating how the "pure noise" coherence behaves.

While it is difficult to understand how these two channels could be correlated at the 60 and 100 Hz harmonics, the significance of these structures ($\gamma^2 > 4\sigma_{\gamma^2}$) and their trends suggest that they are real.

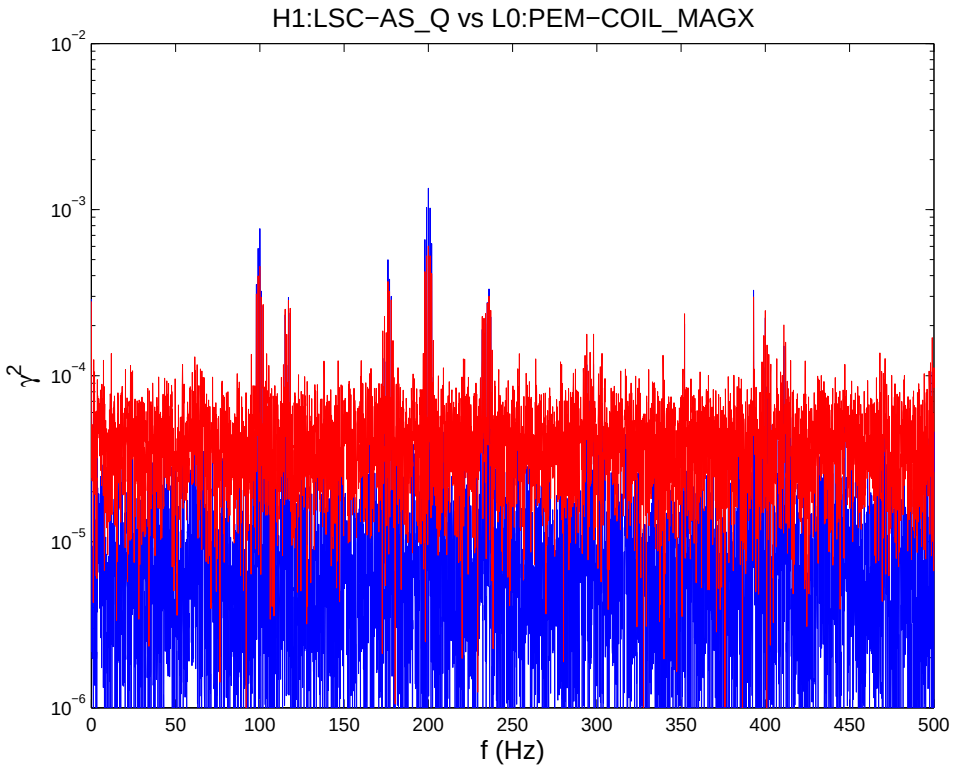

Figure 9: Coherence over all of S4 is shown in blue, $4\sigma_{\gamma^2}$ is shown in red.

3 H0:PEM-COIL_MAGX vs L1:LSC-AS_Q

We now repeat the same analysis using the L1ASQ and the LHO magnetometer. Figure 14 shows the coherence between the two channels over all of S4, and Figure 15 shows the corresponding power spectra. In this case, we do not observe the 60 Hz harmonics, but we do observe some of the 100 Hz harmonics (without the 1 Hz sidebands). Figure 16 shows the coherence over 10 intervals of equal length in S4. Again, we see some small fluctuations in the amplitudes of the 100 Hz harmonics.

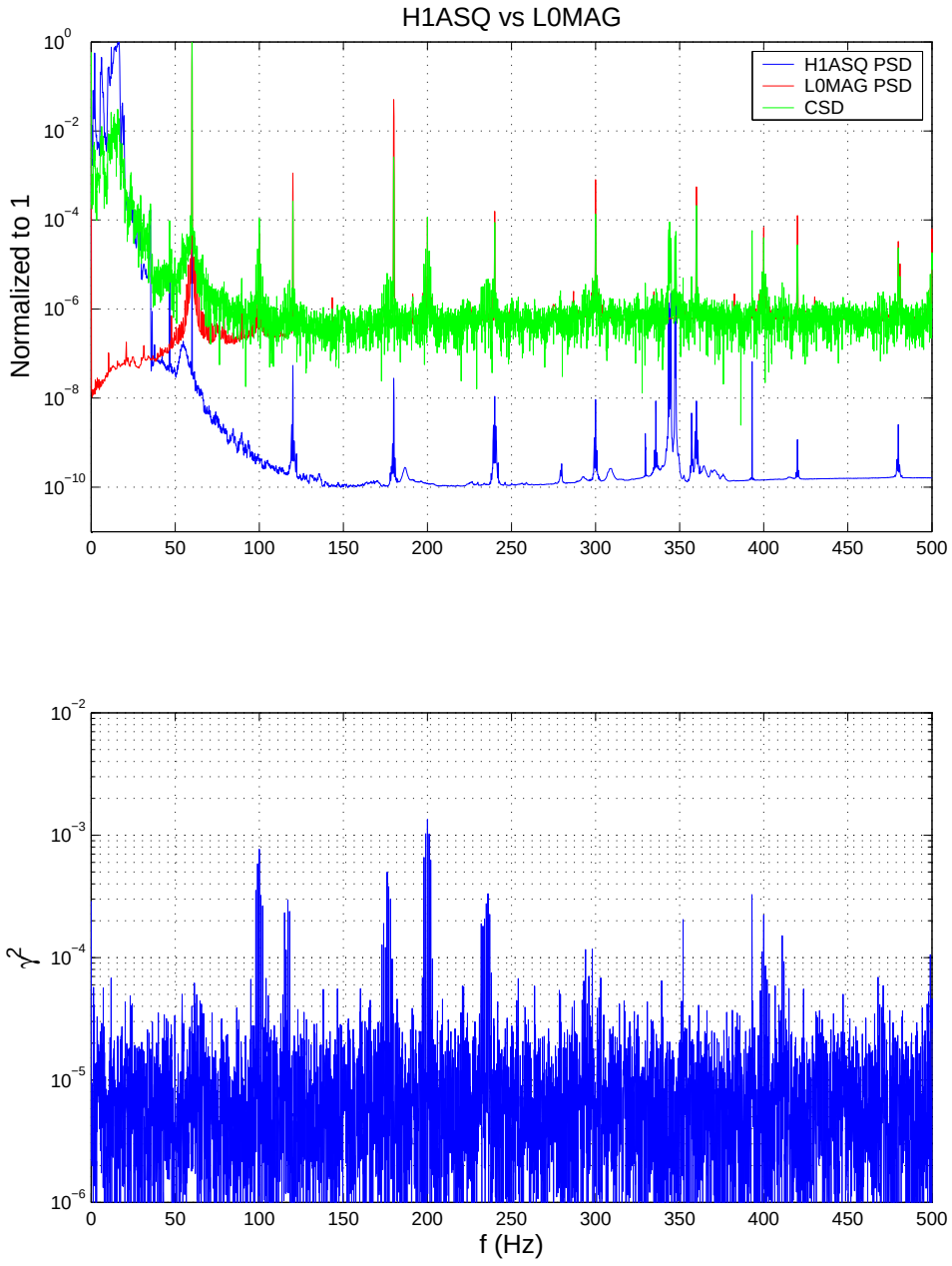

Figure 10: Power spectra and coherence over all of S4.

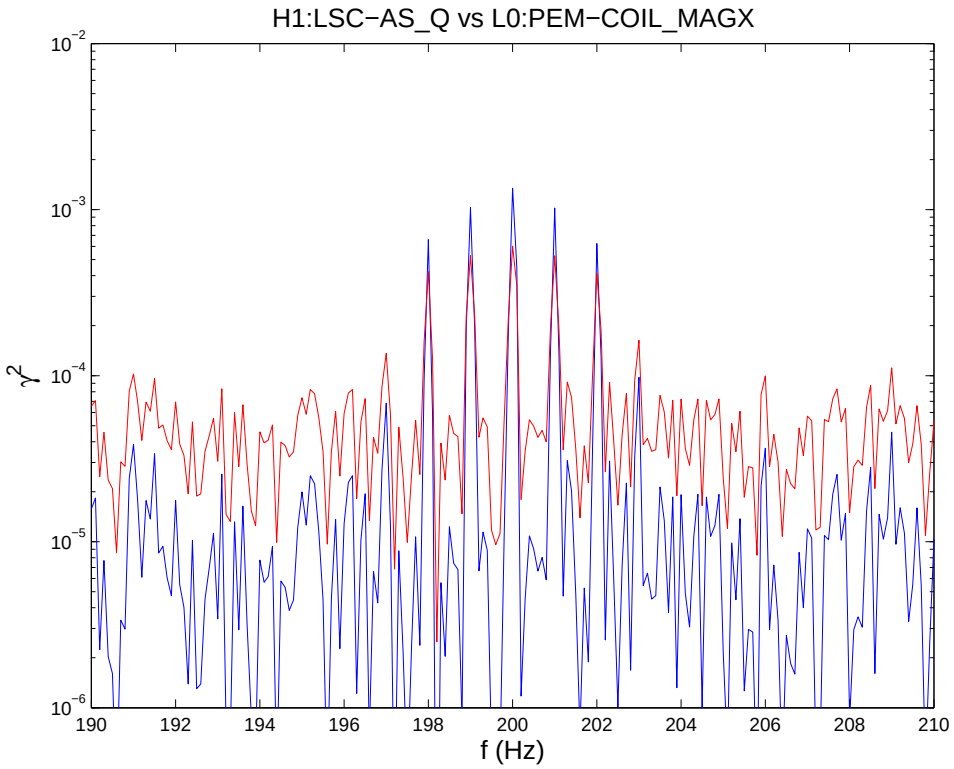

Figure 11: Coherence over all of S4 is shown in blue, $4\sigma_{\gamma^2}$ is shown in red. Zoomed in on 200 Hz peak.

4 H0:PEM-COIL_MAGX vs L0:PEM-COIL_MAGX

Finally, we look at the coherence between the two magnetometer channels, at the two sites. Figure 17 shows the coherence over the whole run and Figure 18 shows the corresponding power spectra. We observe the 100 Hz harmonics from the data logger. However, the broad-band coherence seems also very high (much larger than the estimate of $4\sigma_{\gamma^2}$). Splitting the run into 10 intervals of roughly equal length reveals significant fluctuations. As shown in Figure 19 the broad-band coherence seems significant in most of the intervals. Figure 20 shows trends in two frequency bands - one can observe large long-term fluctuations. Finally, to make sure that this is not a problem with the code I am using, I calculated the coherence between these two channels using DTT - I used the data starting at 795610002 and made 2110 averages. Figure 21 shows that even with DTT we observe a similar effect.

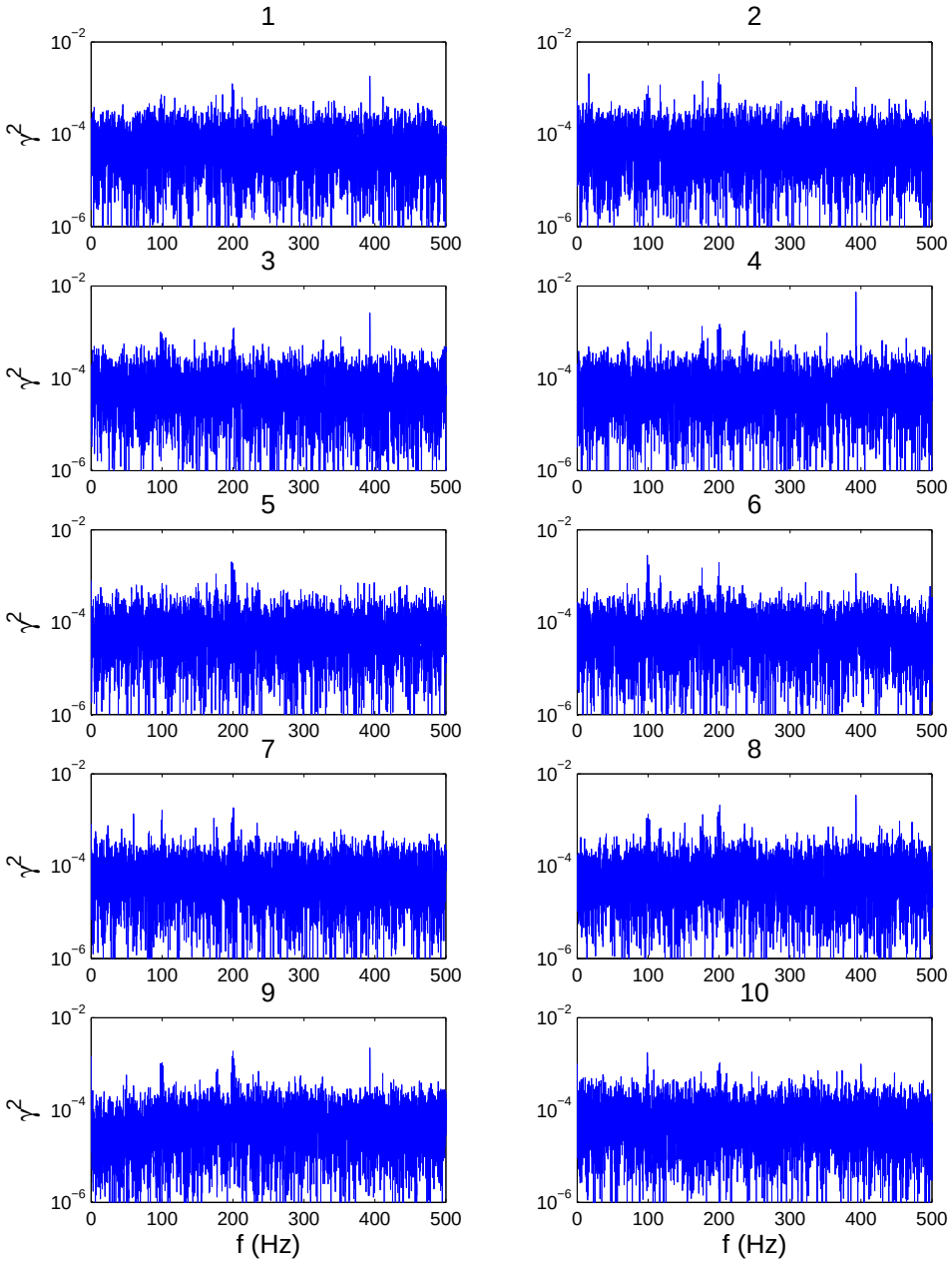

Figure 12: Coherence for 10 intervals of roughly equal length is shown.

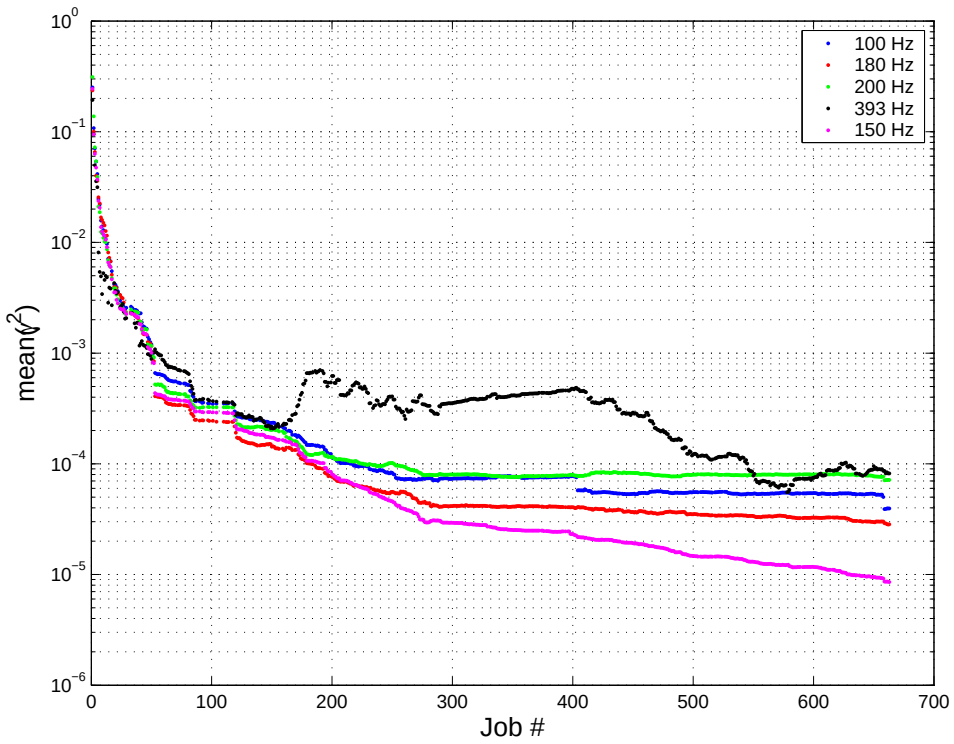

Figure 13: Trends of several lines in the coherence. The "pure noise" 130-170 Hz band (denoted 150 Hz) is included for comparison.

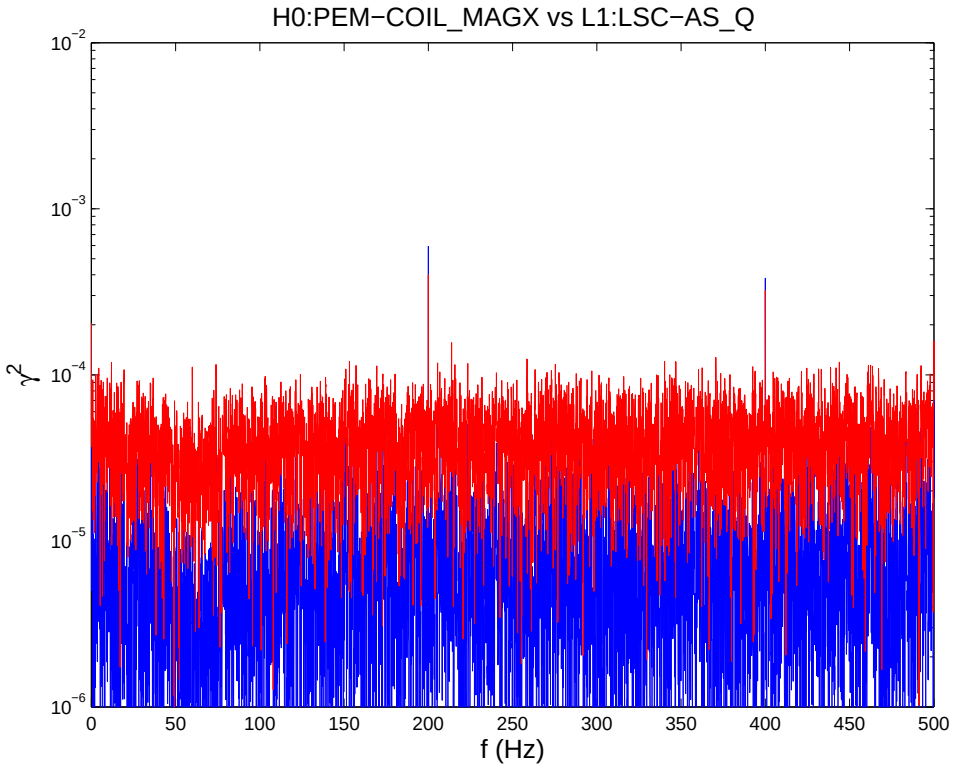

Figure 14: Coherence over all of S4 is shown in blue, $4\sigma_{\gamma^2}$ is shown in red.

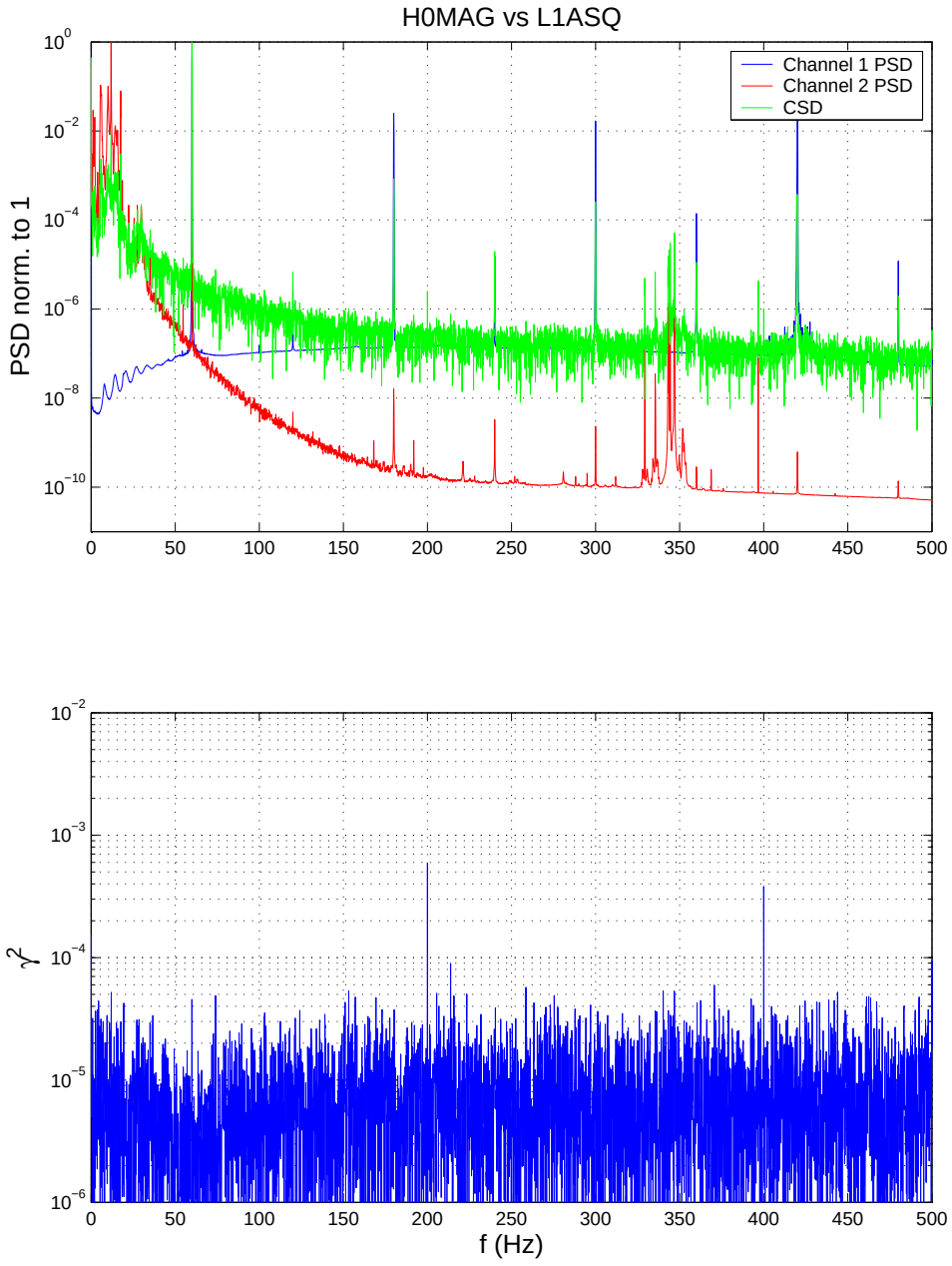

Figure 15: Power spectra and coherence.

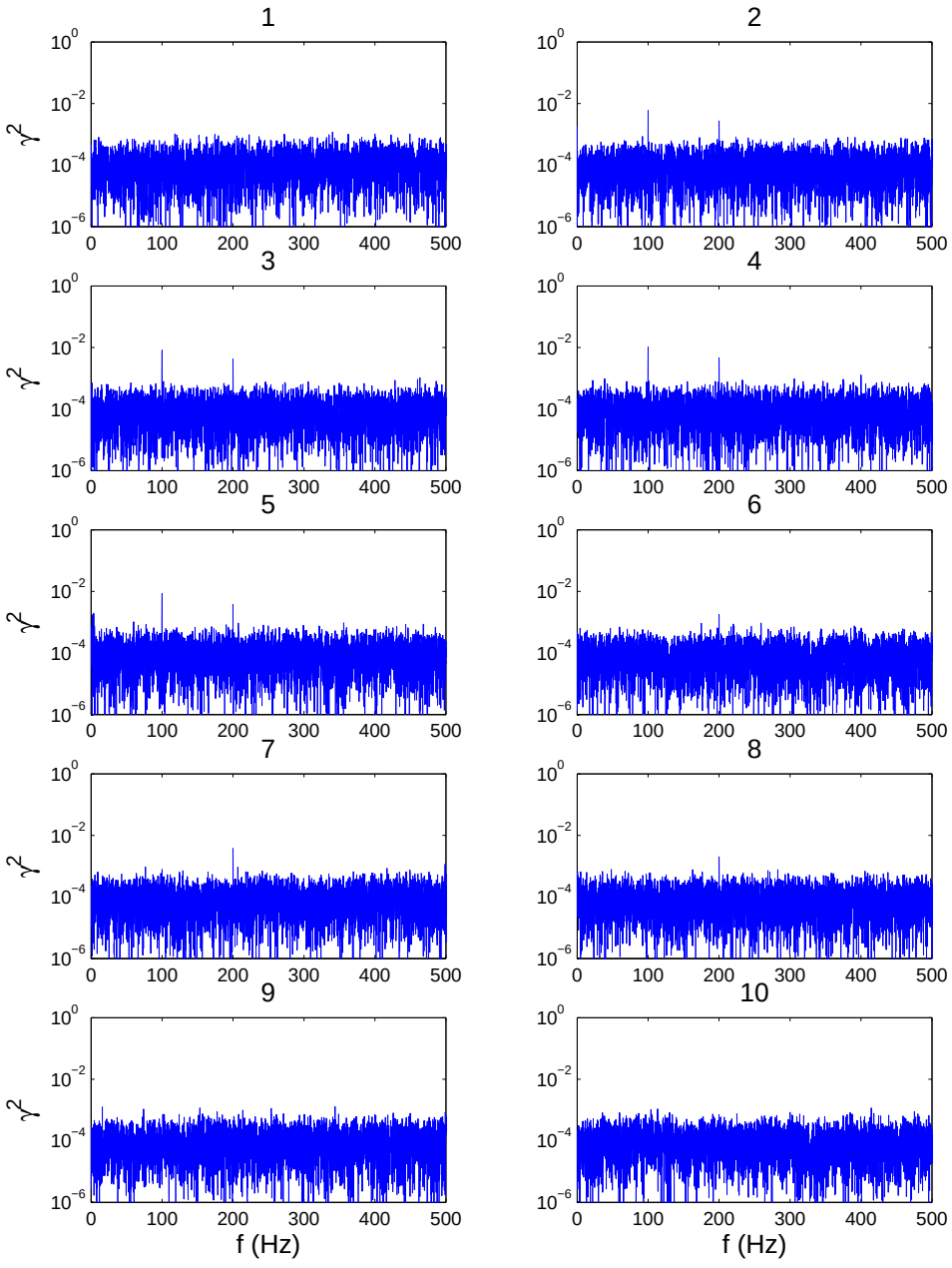

Figure 16: Coherence for 10 intervals of roughly equal length is shown.

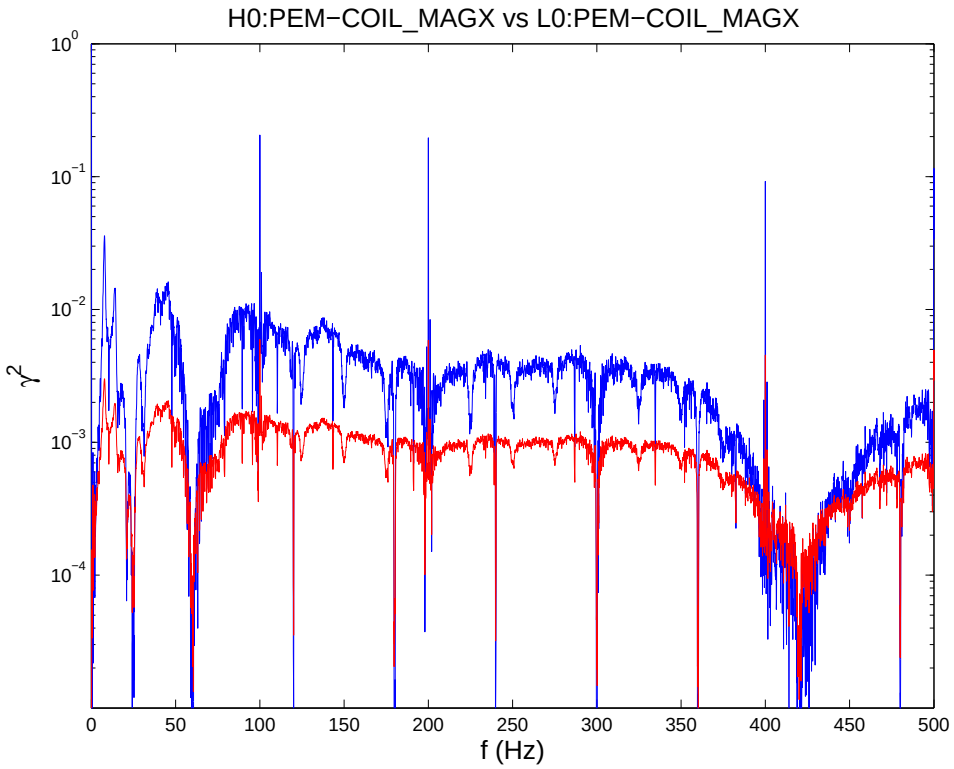

Figure 17: Coherence over all of S4 is shown in blue, $4\sigma_{\gamma^2}$ is shown in red.

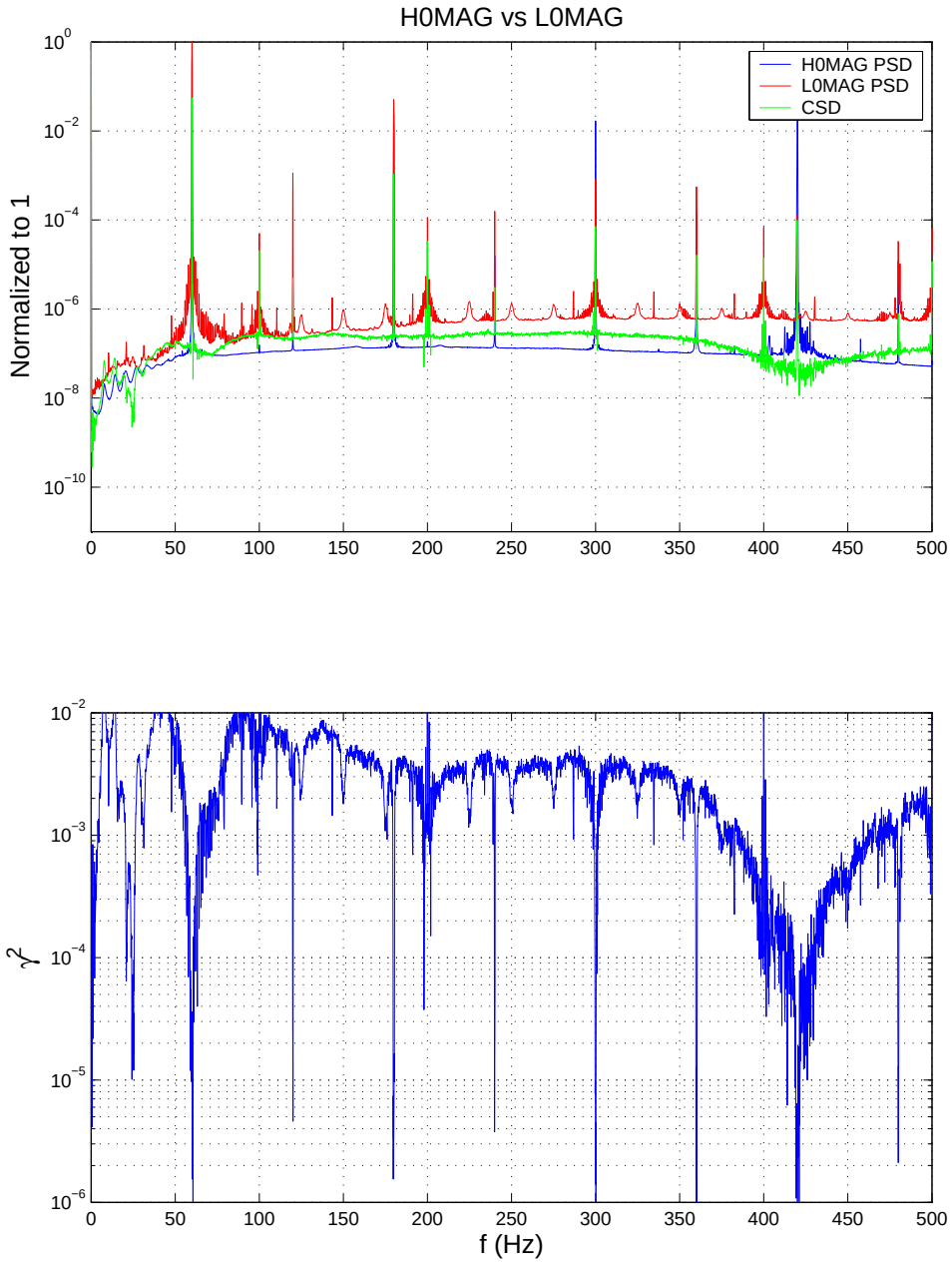

Figure 18: Power spectra and coherence.

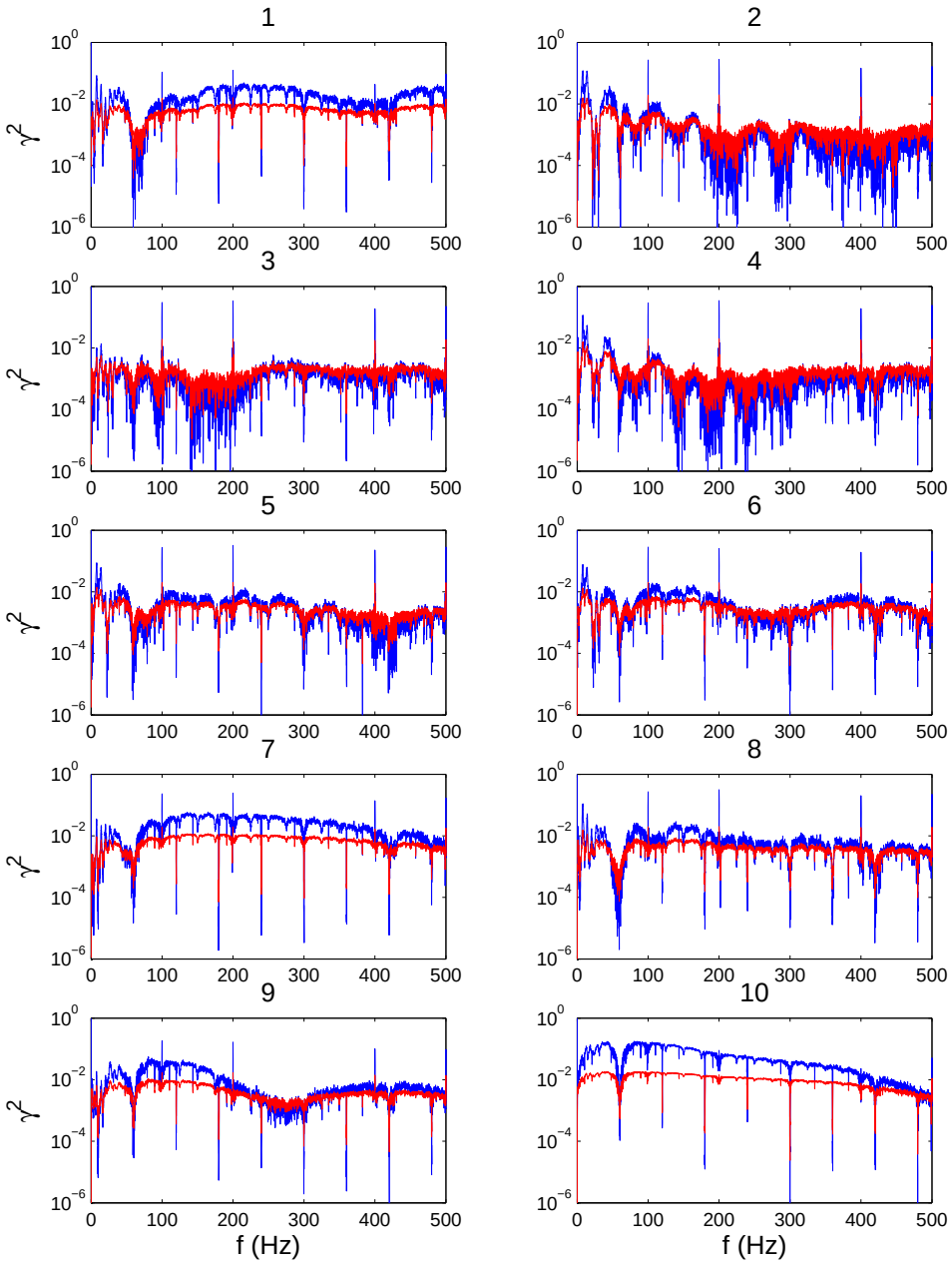

Figure 19: Coherence for 10 intervals of roughly equal length is shown in blue, $4\sigma_{\gamma^2}$ is shown in red.

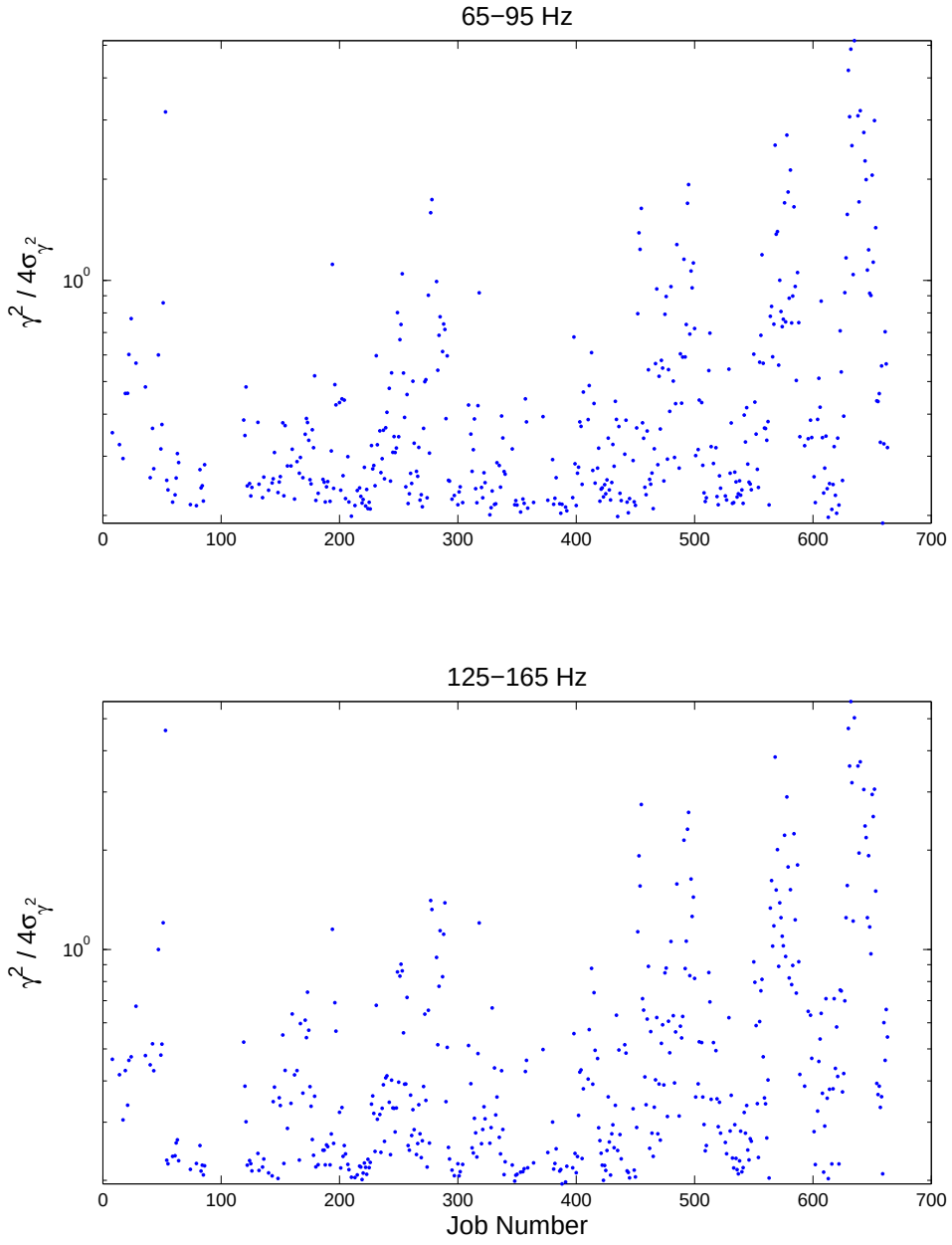

Figure 20: Trends of $\gamma^2/4\sigma_{\gamma^2}$ for two frequency bands. Each point corresponds to one job.

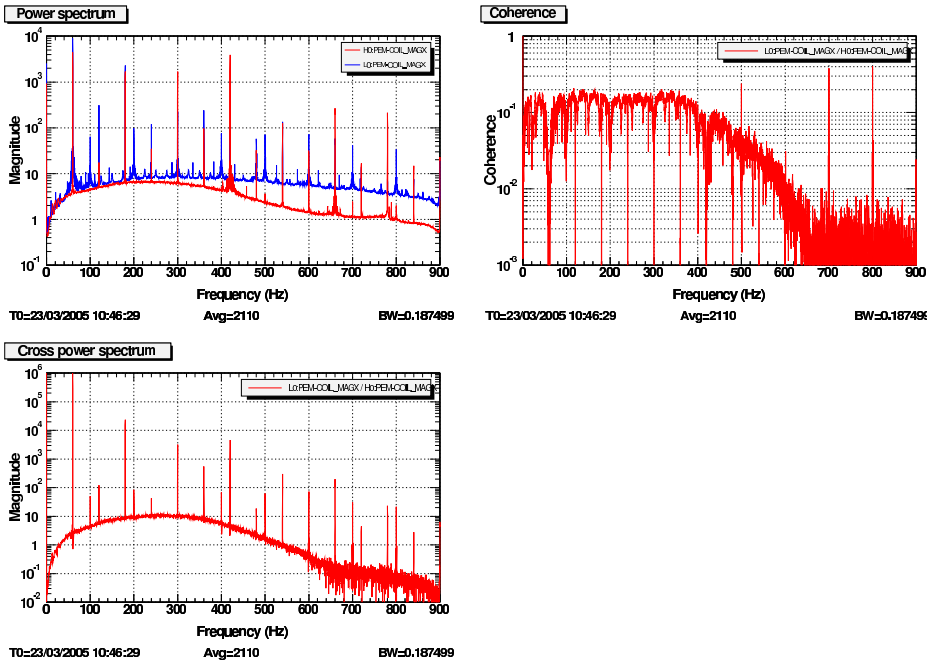

Figure 21: Results using DTT, data starting at 795610002, 2110 averages.