Noise Hunting at Virgo

Elena Cuoco

EGO

on behalf of the Virgo Collaboration

LIGO-G060337-00-Z

A special “thank you” to Irene Fiori

One of our main hunters is now busy...

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28-05-06 LUCA 3,4kg!!!

Outline

1. Our weapons
2. Our prey
   - Spectral lines
   - Non stationary noise
   - Broadband noise
   - Transient-like signals
   - Waveform reconstruction

Our weapons

- Coherence
- Multicoherence
- Time-frequency map
- Non stationary monitor
- Transient signal detection algorithms
- Adaptive lines identification
- Wavelet denoising

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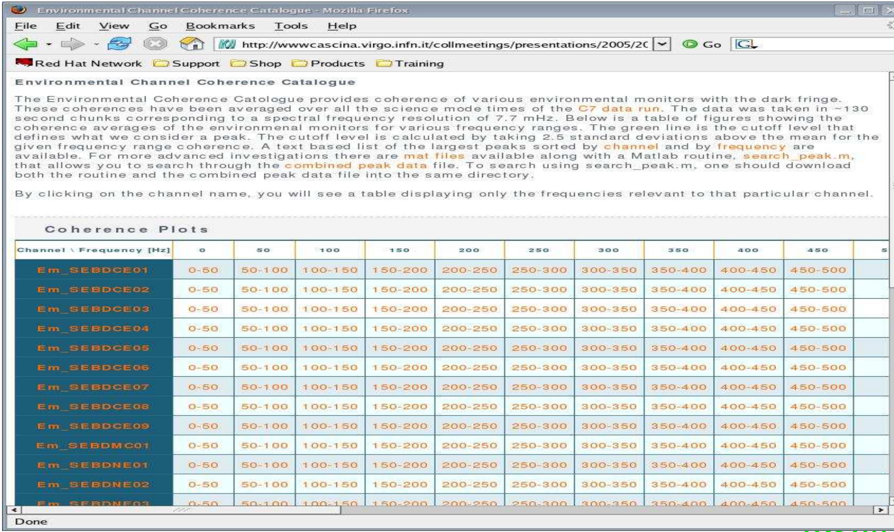
Coherence catalogue



Environmental Channel Coherence Catalogue

The Environmental Coherence Catologue provides coherence of various environmental monitors with the dark fringe. These coherences have been averaged over all the science mode times of the C7 data run. The data was taken in ~130 second chunks corresponding to a spectral frequency resolution of 7.7 mHz. Below is a table of figures showing the coherence averages of the environmenal monitors for various frequency ranges. The green line is the cutoff level that defines what we consider a peak. The cutoff level is calculated by taking 2.5 standard deviations above the mean for the given frequency range coherence. A text based list of the largest peaks sorted by channel and by frequency are available. For more advanced investigations there are mat files available along with a Matlab routine, search_peak.m, that allows you to search through the combined peak data file. To search using search_peak.m, one should download both the routine and the combined peak data file into the same directory.

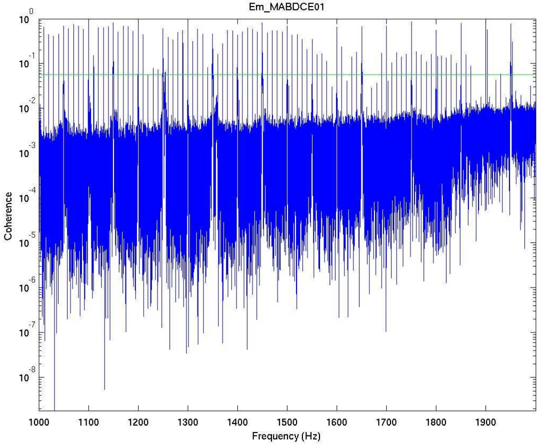
By clicking on the channel name, you will see a table displaying only the frequencies relevant to that particular channel.

Coherence Plots

Channel \ Frequency [Hz]	0	50	100	150	200	250	300	350	400	450	5
Em_SEBDCE01	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE02	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE03	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE04	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE05	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE06	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE07	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE08	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDCE09	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDMC01	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDNE01	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDNE02	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	
Em_SEBDNE03	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	

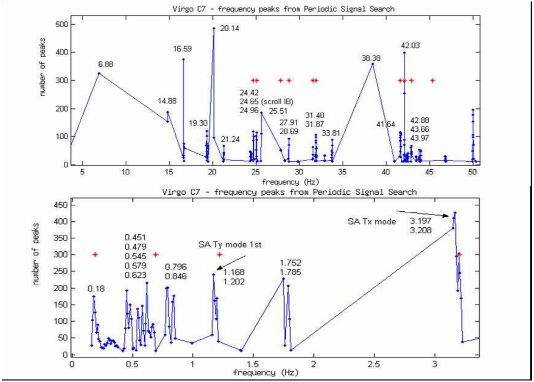
Thanks to N. Christensen

Coherence catalogue



Lines from Pulsar search

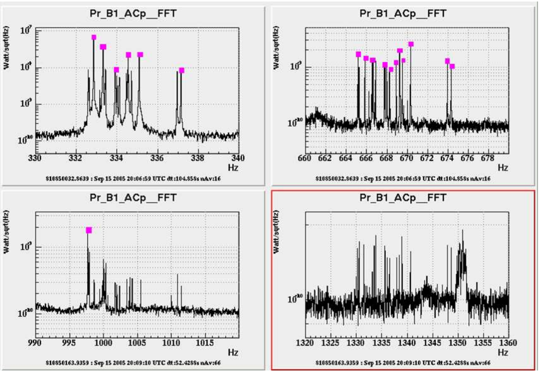
1000 highest frequency peaks from 0 to 2000Hz in C7-run data with resolution of 100s



F	Npeak
353	944
103	776
107	669
667.78	625
336.96	577
334.12	570
333.89	566
333.99	563
670.33	561
667.97	561
667.75	558
...	...

Violin modes

Lines in the range 330-340Hz are the fundamental violins modes of wires suspending NE, WE, NI, WI, thermally excited.



We expected 32 distinct fundamental modes (4 mirrors x 4 wires x 2 modes) . We identified 28 modes!

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Non stationary monitor

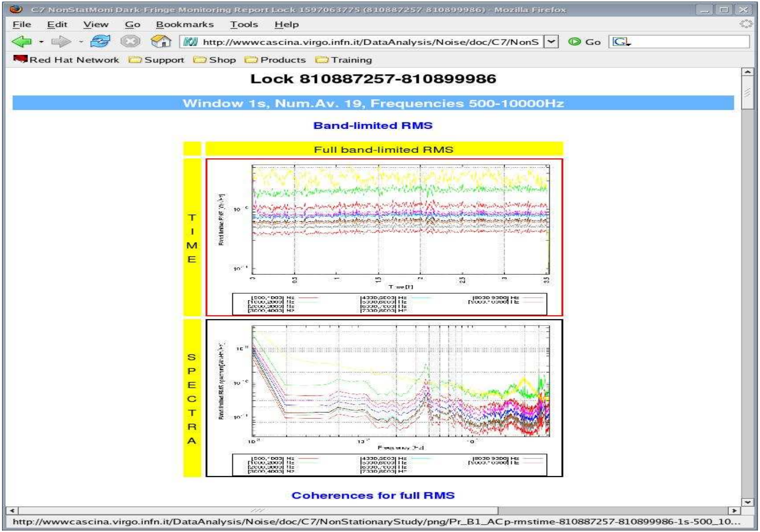
Computed band limited RMS with bands:

- [0 10] [10 25] [25 60] [60 100] [100 200] [200 500] [500 1000] [1k 5k] [5k 10k] Hz
- [0.1 0.2] [0.2 0.3] [0.3 0.4] [0.4 0.5] [0.5 0.6] [0.6 0.7] [0.7 0.8] [0.9 1] kHz
- [1 2] [2 3] [3 4] [4 5] [5 6] [6 7] [7 8] [8 9] [9 10] kHz

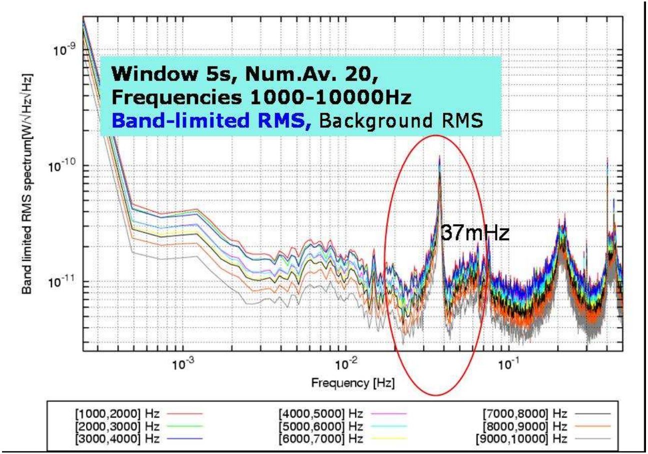
Spectral analysis good between 1 mHz and 500 mHz

G.Vajente

Non stationary monitor



Non stationary monitor

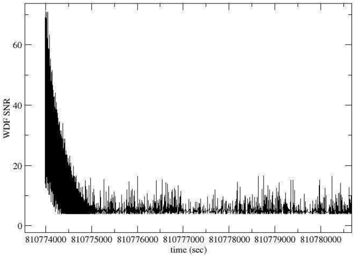


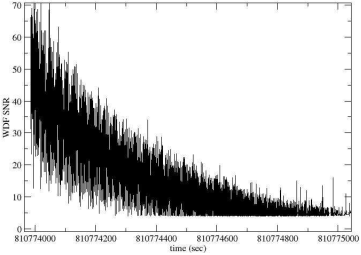
NB

LF angular noise couples to narrow and intense lines in Dark Fringe increasing significantly noise level nearby

Post lock ringdown

Just after the lock of the ITF, a noiser period is present

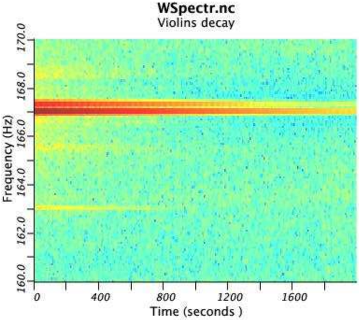




Using whitening and adaptive lines identification method, we identified the main excited resoncances...

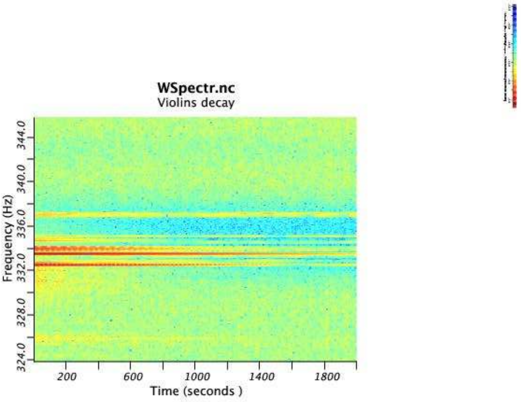
Excited resonances identifi cation

@167Hz



Excited resonances identifi cation

@333Hz



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Multicoherence and noise removal

s is our signal
n_i a set of auxiliary noise signals
τ_i set of coefficients for the linear trasformation

$$C(\omega) = \begin{matrix} ss & sn_1 & sn_2 & sn_3 \\ sn_1 & n_1n_1 & n_1n_2 & n_1n_3 \\ sn_2 & n_2n_1 & n_2n_2 & n_2n_3 \\ sn_3 & n_3n_1 & n_3n_2 & n_3n_3 \end{matrix}$$

$$s'(\omega) = s(\omega) - \sum \tau_i(\omega) n_i(\omega)$$

$$< a(\omega) b^*(\omega') >= 2\pi\delta(\omega - \omega') C_{ab}(\omega)$$

$$min_{\tau_i} C_{s's'}(\omega)$$

G. Cella, Off-Line Subtraction of Seismic Newtonian Noise,QC173.6 .R44 2000
B. Allen et al., gr-qc/9909083

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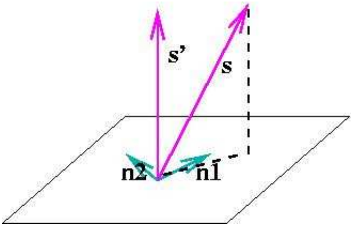

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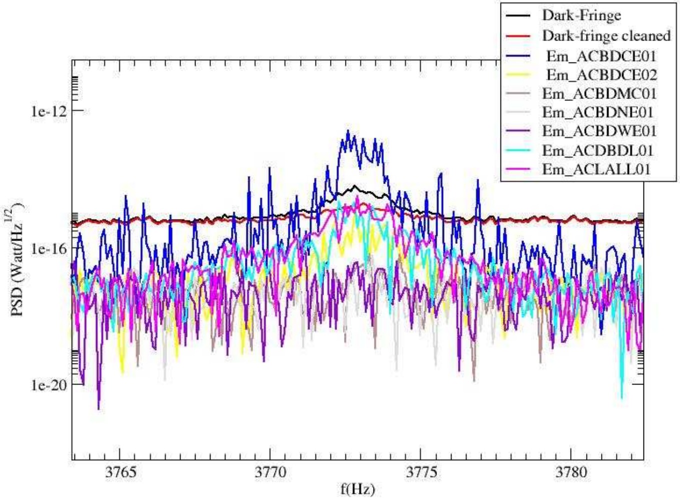
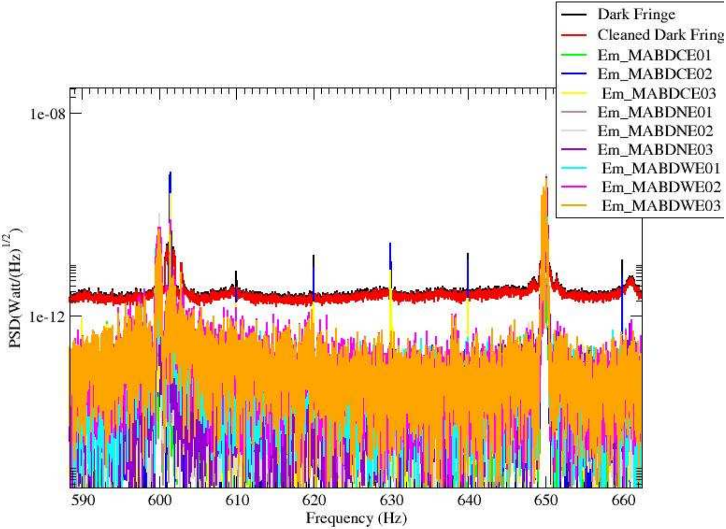
Example : acoustic noise removal



Example II: lines @10Hz



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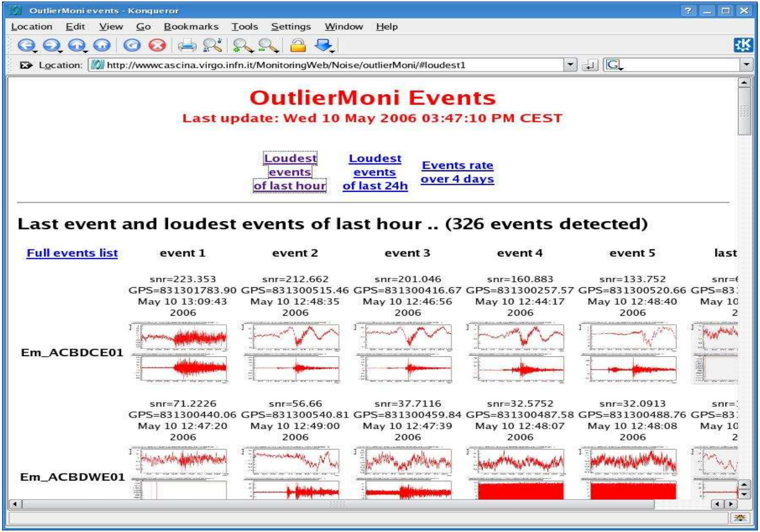
Burst detection tools

Transient detection algorithms

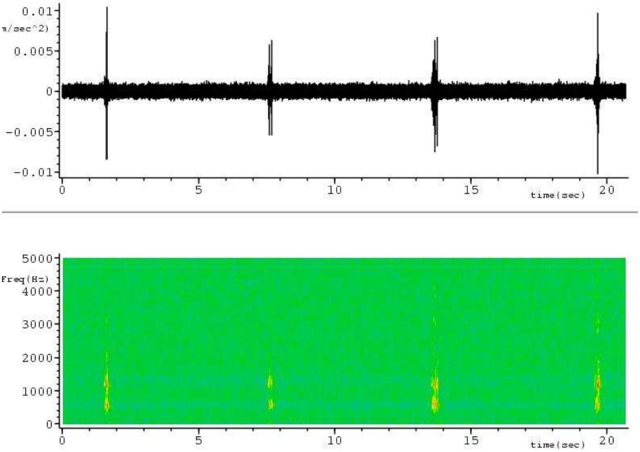
- Mean Filter
- Wavelet detection filter
- Power Filter
- OutlierMoni
- Peak correlator

Coincidences among auxiliary channels and DF to build vetoes procedure!

Burst detection tools



Example I:Detection bench accelerometer



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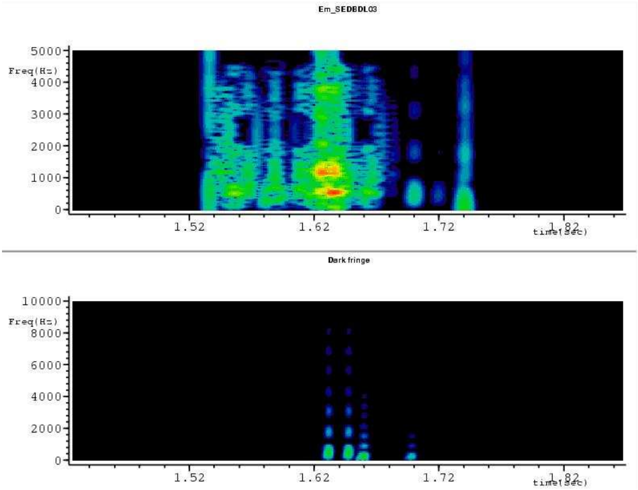

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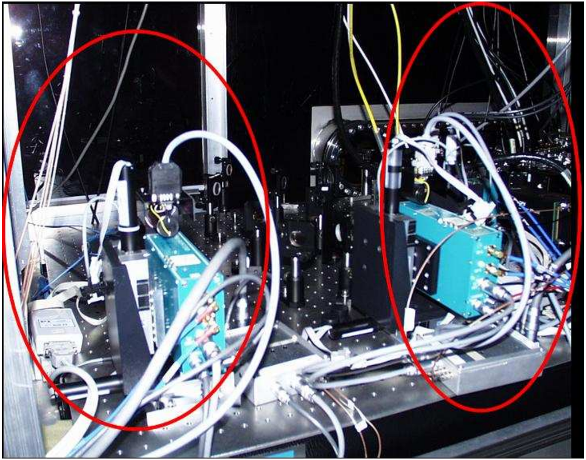
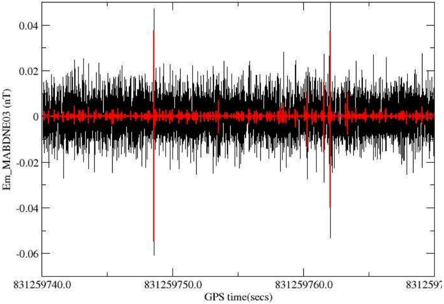
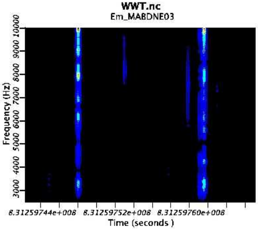


Example II: lightening

Whitened signal in a magnetometer





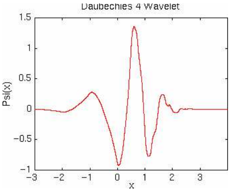
Outline

The wavelet transform

The wavelet transform of a signal $f(t)$ is defined as

$$Wf(a,b) = < f, \psi_{a,b} > = \int_{-\infty}^{+\infty} f(t) \frac{1}{\sqrt{b}} \psi^*(\frac{t-a}{b}) \; dt \qquad (1)$$

where the base is a zero average function, centered around zero and with a finite energy. The entire base is obtained by translations and dilations of the base atom:



$$\psi_{ab}(t) = \frac{1}{\sqrt{b}} \psi(\frac{t-a}{b}) \quad (2)$$

The discrete wavelet transform (DWT) is an implementation of the wavelet transform using a discrete set of the wavelet scales and translations.

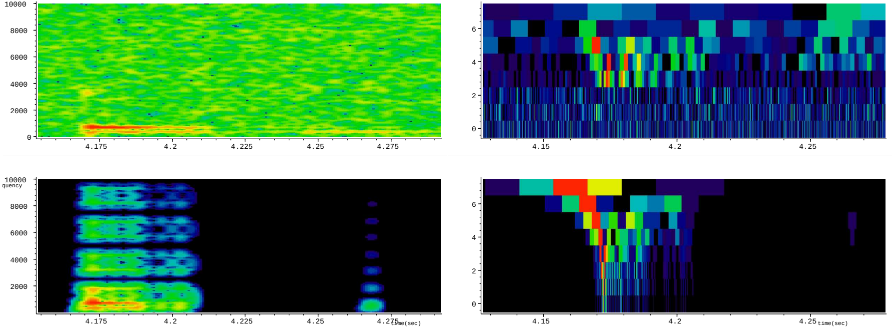
The Donoho-Johnston thresholding

To select the highest coefficients, we have to compare each coefficient with e threshold.
We used the universal Donoho and Johnstone method for the threshold

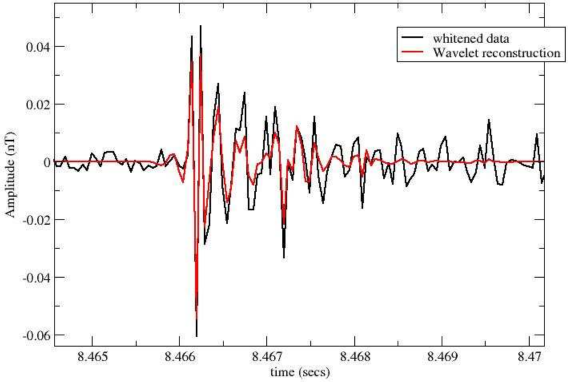
$$t = \sqrt{2 \log N} \hat{\sigma} \tag{3}$$

where N is the number of data points and $\hat{\sigma}$ is an estimate of the noise level variance.
We used as estimate for the $\hat{\sigma}$ the one obtained using the AR parametric fit to the data.
We can also choose to use and adaptive estimation for the $\hat{\sigma}$.

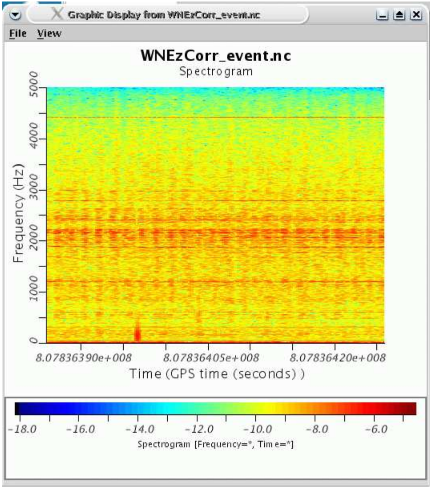
An example on a transient real signal (dark fringe channel)

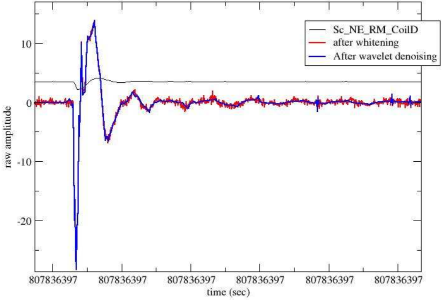


Example I: lightening waveform



Example II: glitch on coil





Summary

- A full monitoring system for noise identification and noise removal has been set-up
- As soon as Virgo will reach the design sensitivity, the dark fringe will show up new noise sources
- Data conditioning tools must be ready for GW signal detection