The on-line data filters for EXPLORER and NAUTILUS

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Abstract

The basic problem with GW detectors is to detect very small signals in presence of noise which is not Gaussian and also not stationary.
We cope with this problem by applying data filters, matched to short bursts, based on power spectra obtained on-line. We describe here the new procedure adopted by the Rome group, where the signal-to-noise ratio obtained with various algorithms are compared and the best one is selected.
The selected algorithm depends on the noise characteristics at that particular time.

1. Introduction

In the last few years the Rome group has used a data acquisition system with a sampling time of 220 Hz [1]. With the new daga2_hf acquisition system [2], the data are sampled at the frequency rate of 5000 Hz. The signal is then processed with a software procedure to extract the sensitive band of the antenna that is about of 20 Hz. These samples are collected in sets of 8192 samplings in the time domain, for a total time of 105 s. From these data periodograms are calculated.
The periodograms are exponentially and autoregressively averaged, with a varying memory time, for obtaining the adjourned spectrum needed for estimating the matched filter.
Three different procedures for combining the various periodograms are used, called CLEAN, ADAPTED and WHOLE.
We use the following recursive equation:

$$S_i = P_i(1-W) + WS_{i-1} \qquad [1]$$

where P_i is the actual periodogram, S_i is the actual spectrum and the coefficient $W=e^{-\Delta t/\tau}$ characterizes the system memory by means of the time constant τ.
All the procedures estimate the spectrum using eq. [1], but they differ one from each other for the different time constant in the spectrum averaging procedure, and for the selection of the periodograms.

2.The whole filter

The whole filter is the simplest implementation of eq. [1]. In this filter W is a constant where τ is fixed at one hour. The WHOLE filter uses all the periodograms to obtain the matched filter, so it is a good filter for the case of stationary noise but it does not resolve the problem of the short disturbances. In fact when we include a noisier periodogram in the eq. [1], due to a disturbances even with a short time duration, we degrade the spectrum estimate.

3.The clean filter

The problem of the short time disturbances can be resolved by eliminating the correspondent periodogram in the spectral estimation. This is performed in the CLEAN filter where W is still constant but it uses only *good* periodograms, keeping a clean spectrum.

The choice of the *good* periodogram is performed evaluating the integral of the power spectrum of the data in the following way. The integral of the power spectra has value σ and S is his expected value. The periodogram is not used for the filter power spectra if $\sigma \geq k*S$, where k is a constant.

The spectrum obtained by this procedure does not have excess noise and the CLEAN filter has a good performance when short disturbances are present. The fig. 1 shows the integral of the periodograms when a disturbance occurs after the 12 hours. Each periodogram is calculated over 105 s and we can see its large value, above threshold, just after the disturbance and its recovery.

The dashed line indicates the threshold, k*S, for the selection of the periodograms.

The fig. 2 shows a comparison between the data filtered using the WHOLE and the CLEAN filters. We note that by the elimination of the noisier periodograms we not degrade the spectra and the t_{eff} (average value of the filtered data which indicates the noise expressed in kelvin units) obtained with the CLEAN filter after a short disturbance is better than that obtained with the whole filter.

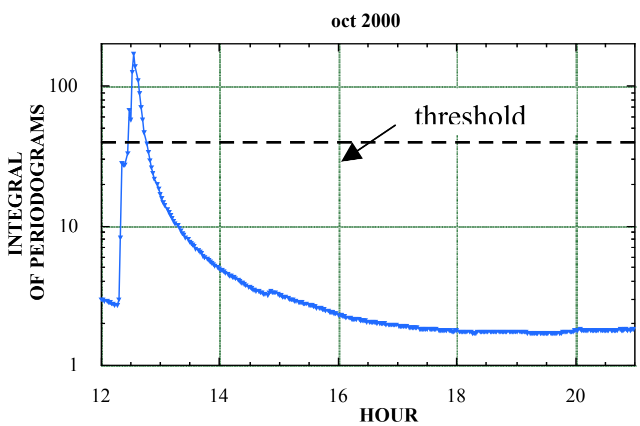

Figure 1. Integral value of the periodograms.

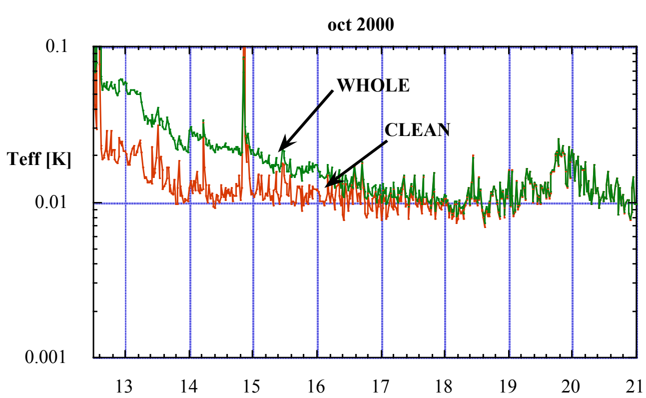

Figure 2. Comparison of the Whole and Clean filters.

2. The adapted filter

When the data are noisier for a long time period we must use the *noisier data* to estimate the power spectra. In this situation the CLEAN filter is not a good filter.
The ADAPTED filter updates continuously but his memory time τ changes to adapt itself to the quality of the data according to the following equation

$$\tau = \frac{2\tau_0}{1+\chi} \qquad \chi = \frac{\sigma}{S} \qquad [2]$$

The memory time decreases during the noisier time period and is constant in the situation of very good data.
The fig.3 shows a comparison between the data filtered by the CLEAN and the ADAPTED filters during a time period when we have noisier data for about two-hours.
As we can ee, in this situation, the Adapted filter gives a lower noise temperature.

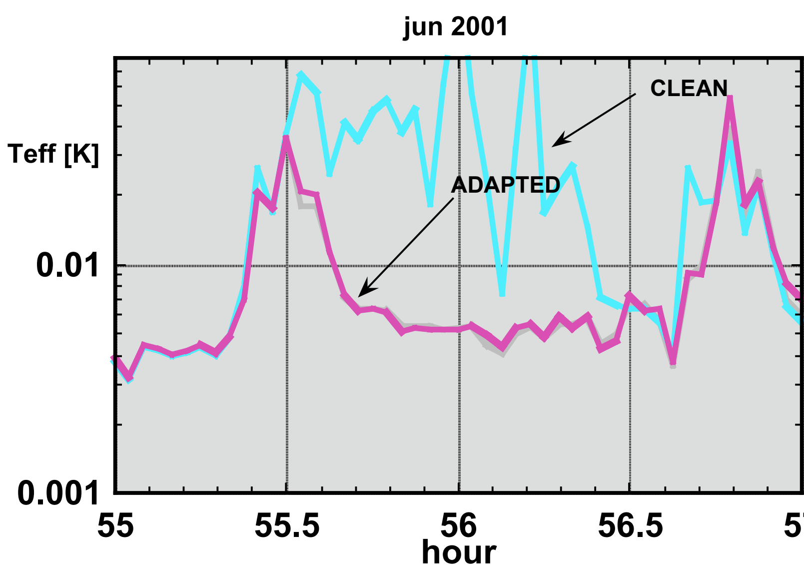

Figure 3. Comparison between the adapted and the clean filters.

4.Conclusions

Data may be acquired with very different characteristics of the noise and if one use always the same filter he cannot obtain the best result in all cases.

The strategy of the new daga2_hf acquisition system consists in filtering the data with three algorithms and in choosing the data coming from the one giving the higher SNR.

The competitive uses of the three filters can improve the performance of the detector.

For example, using the Nautilus data recorded in the year 2001, we increase the time when the noise is the smallest, as indicated in the figure 4, which shows the time percentage when the noise temperature is below 5mK, between 5 and 10mK etc.. The final result is obtained by choosing the best SNR among those calculated with the whole, clean and adapted filters.

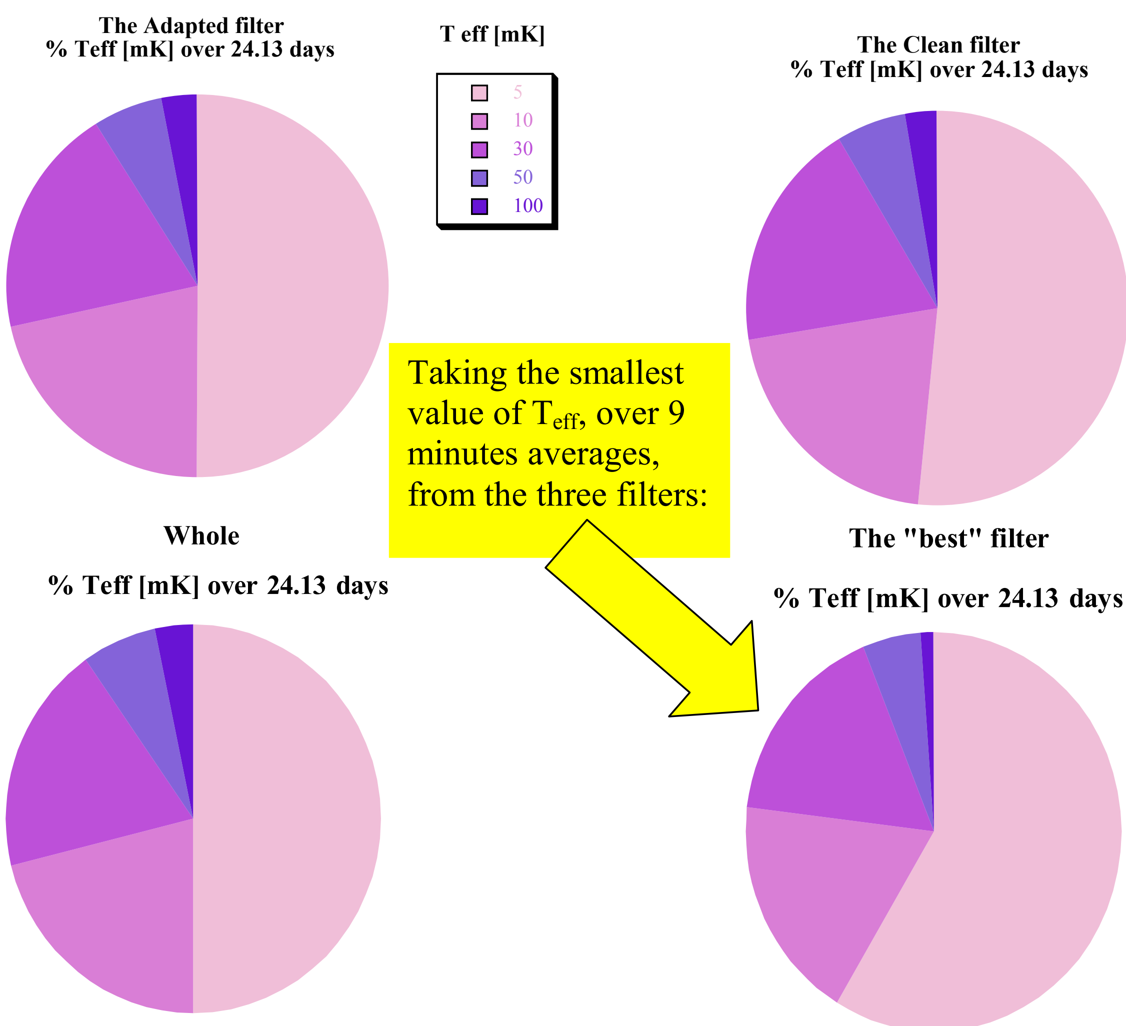

Figure 4. Time percentage when the noise temperature is below 5mK, between 5 and 10mK etc., for the various filters.

References

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