Detection of periodic sources with more antennas

(by incoherent adaptive method)

Sergio Frasca, March 2007

A "network" search for periodic sources can be performed in three different basic ways:

a) coherently summing the output of the various antennas, with certain weights and delays, or doing a more-than-one antenna f-statistics
b) constructing with the data of the different antennas a single "incoherent step" (e.g., a single Hough map)
c) doing the coincidences between the candidates of the different antennas (in possibly different time periods); this method is "unavoidable", because it is the main method to check the validity of candidates.

This analysis has been performed using a method of type b). In this case, we create, for each value of the frequency and spin-down, a single adaptive Hough map (see Palomba et al. in Class. Quantum Grav. **22** (2005) S1255–S1264), taking the spectral peaks from more antennas.
Because of the general type of this analysis, here the radiation pattern has not been considered.

If one has data from M antennas, and each antenna has a stationary noise H_k and has been observed for N_k coherent periods (in the case of Virgo is the number of FFTs) , the joint analysis gives result equivalent to the analysis done on a single stationary antenna with

$$N = \sum_{k=1}^{M} N_k$$

coherent periods and a stationary noise (that we call *equivalent noise*)

$$H(\nu) = \frac{1}{\sqrt[4]{\frac{1}{N}\sum_{i=1}^{M}\frac{N_i}{H_i^4(\nu)}}}$$

The 4th power and root highly rejects weaker antennas. Note that

$$N \approx \frac{T_{obs}}{T_{coh}}$$

where T_{obs} is the observation time and T_{coh} is the length of the first coherent step.

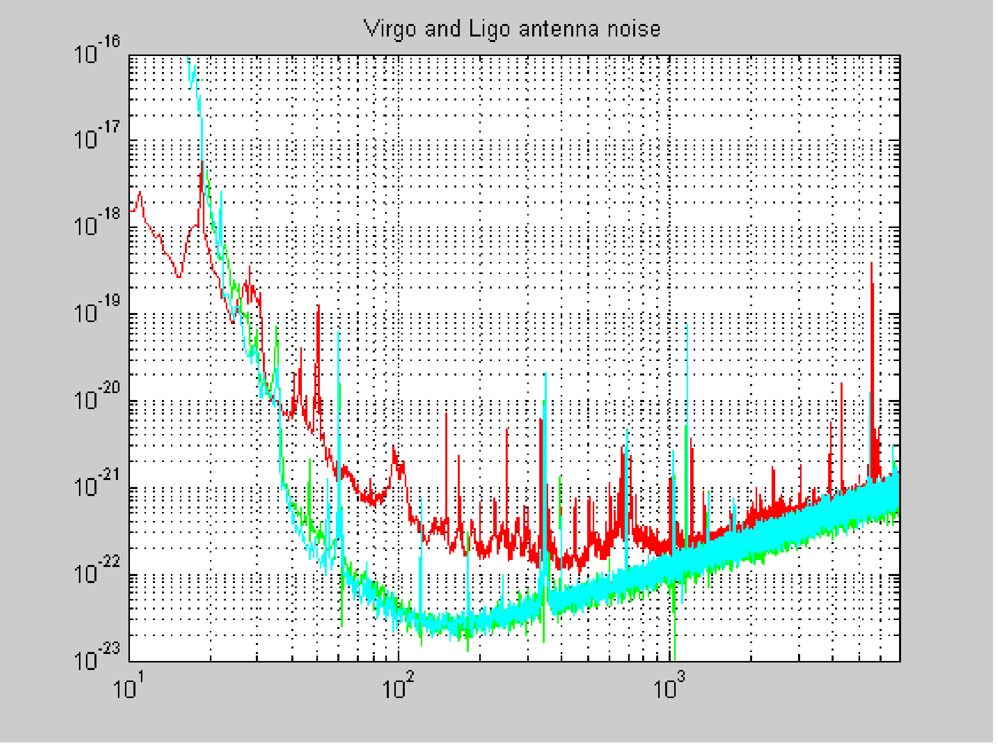
The sensitivity of the analysis is

$$h_{0\min} = 1.94 \cdot \sqrt{\frac{\theta}{T_{coh}}} \cdot \frac{1}{\sqrt[4]{\sum_{i=1}^{M} \frac{N_i}{H_i^4(\nu)}}}$$

where θ is the threshold in CR on the Hough maps.

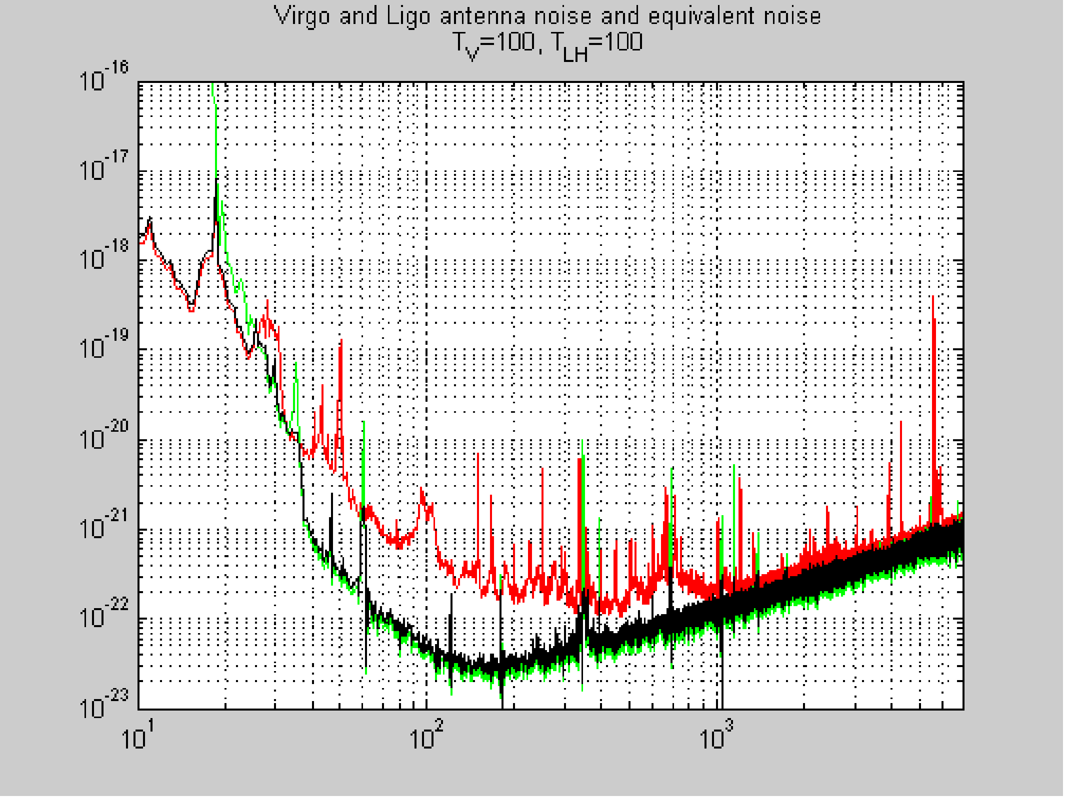
Note that this incoherent analysis can benefit also if the observation periods of the antennas are not parallel (contemporary).

We started from the WSR9 Virgo (red) data and S5 Ligo data (green and cyan):

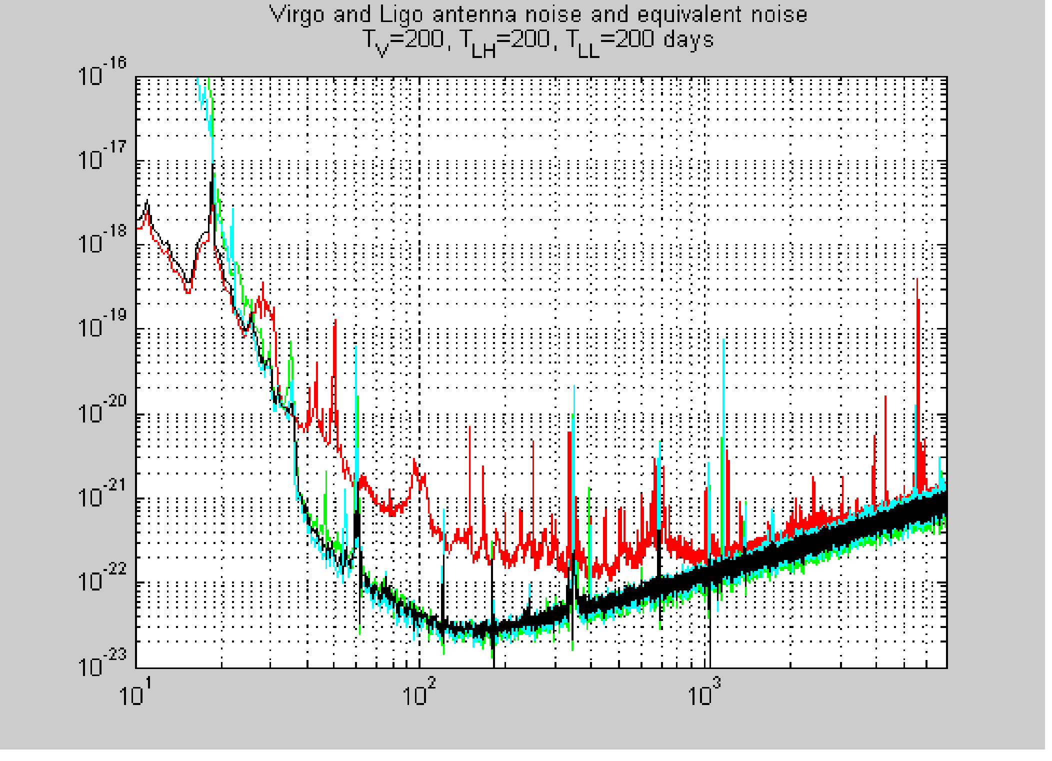


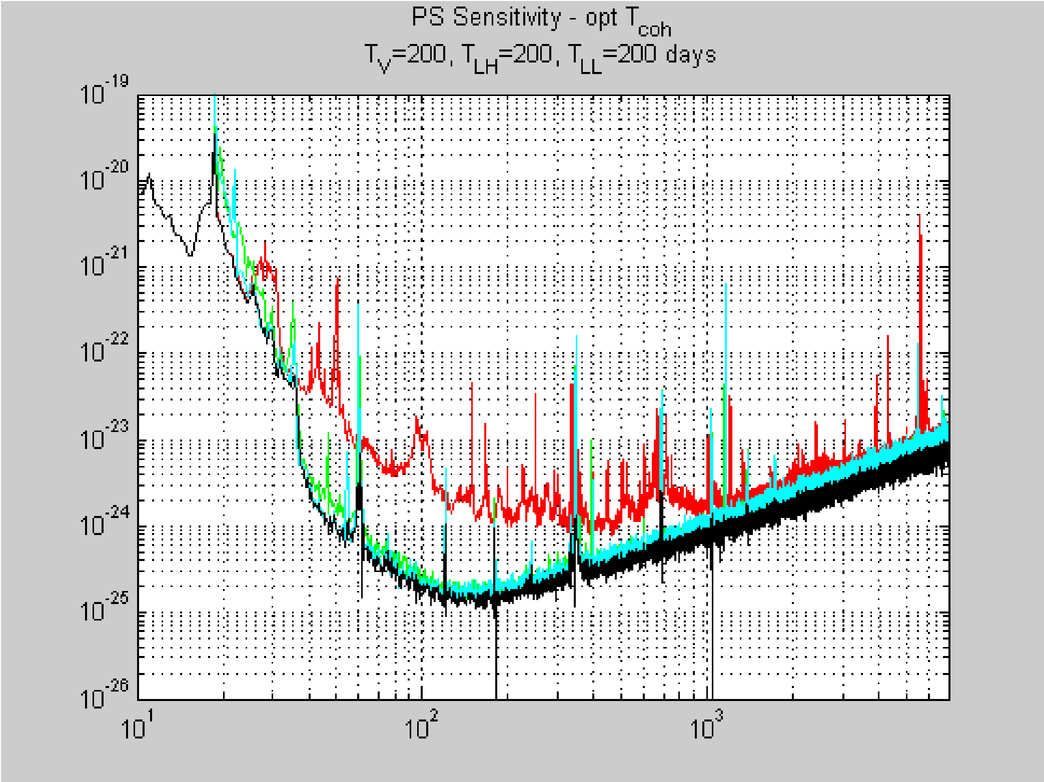
Here are some results:

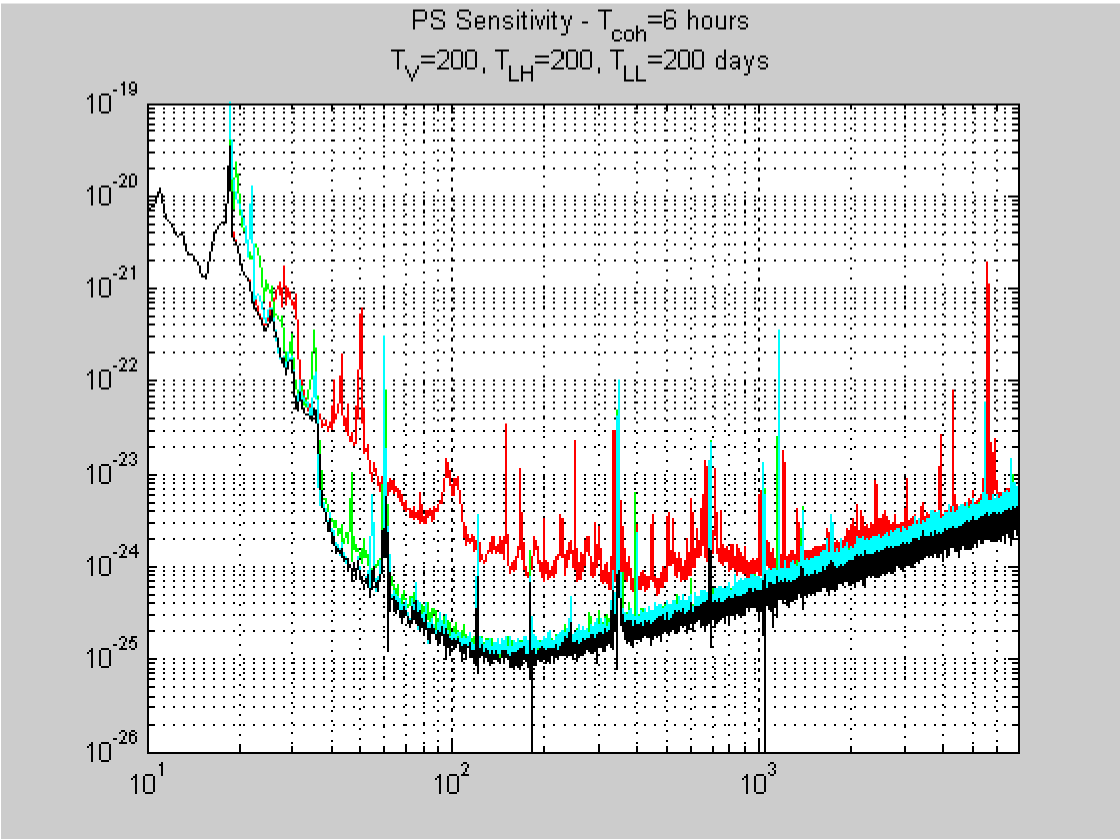
- Virgo and one Ligo antenna, 100 days each: single antennas noise and equivalent noise (black).



- Virgo and two Ligo antennas, 200 days each: equivalent noise (with single antennas noise), PS sensitivity with SFT length T_{COH}, PS sensitivity with T_{COH}= 6 hours.




PS Sensitivity - opt T_{coh}
T_V=200, T_{LH}=200, T_{LL}=200 days
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{1}
10^{2}
10^{3}


PS Sensitivity - T_{coh}=6 hours
T_V=200, T_{LH}=200, T_{LL}=200 days
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{1}
10^{2}
10^{3}

Snag Code

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% rep_nonstat_sens

cd D:\SF_DatAn\pss_datan\Quality\Sensitivities
load_sens

[ligH ligL]=parall_gd(LHO_S5,LLO_S5,0.5);

[vir ligH]=parall_gd(SensitivityH_WSR9,ligH,0.5);
figure,loglog(vir,'r',ligH,'g',ligL,'c'),grid on
title('Virgo and Ligo antenna noise')
xlim([10 7000])
ylim([10^-23 10^-16])

sens(1).h=vir;
sens(1).tobs=200;
sens(2).h=ligH;
sens(2).tobs=200;
sens(3).h=ligL;
sens(3).tobs=200;

sens1=sens(1);
sens2=sens(2);
sens3=sens(3);
[s1 eq1]=pss_ns_sens(sens1,3.8);
[s2 eq2]=pss_ns_sens(sens2,3.8);
[s3 eq3]=pss_ns_sens(sens3,3.8);
[s eq_nois]=pss_ns_sens(sens,3.8);

% figure,loglog(vir,'r',ligH,'g',ligL,'c',eq_nois,'k'),grid on
figure,loglog(eq1,'r',eq2,'g',eq3,'c',eq_nois,'k'),grid on
title({'Virgo and Ligo antenna noise and equivalent noise' ...
    sprintf('T_V=%d, T_L_H=%d, T_L_L=%d
days',sens1.tobs,sens2.tobs,sens3.tobs)})
xlim([10 7000])
ylim([10^-23 10^-16])
figure,loglog(s1,'r',s2,'g',s3,'c',s,'k'),grid on
title({'PS Sensitivity - opt T_c_o_h' ...
    sprintf('T_V=%d, T_L_H=%d, T_L_L=%d
days',sens1.tobs,sens2.tobs,sens3.tobs)})
xlim([10 7000])
ylim([10^-26 10^-19])

s1l=pss_ns_sens(sens1,3.8,3600*6);
s2l=pss_ns_sens(sens2,3.8,3600*6);
s3l=pss_ns_sens(sens3,3.8,3600*6);
sl=pss_ns_sens(sens,3.8,3600*6);

figure,loglog(s1l,'r',s2l,'g',s3l,'c',sl,'k'),grid on
title({'PS Sensitivity - T_c_o_h=6 hours' ...
    sprintf('T_V=%d, T_L_H=%d, T_L_L=%d
days',sens1.tobs,sens2.tobs,sens3.tobs)})
xlim([10 7000])
ylim([10^-26 10^-19])

sensopt(1)=sens1;
sensopt(1).tobs=sens1;
sensopt(2)=sens2;
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sensopt(1).tobs=100;
sensopt(2).tobs=100;
sensopt1=sensopt(1);
sensopt2=sensopt(2);

[sopt eq_noisopt]=pss_ns_sens(sensopt,3.8);
[s11 eq11]=pss_ns_sens(sensopt(1),3.8);
[s22 eq22]=pss_ns_sens(sensopt(2),3.8);

figure,loglog(eq11,'r',eq22,'g',eq_noisopt,'k'),grid on
title({'Virgo and Ligo antenna noise and equivalent noise' ...
    sprintf('T_V=%d, T_L_H=%d',sensopt(1).tobs,sensopt(2).tobs)})
xlim([10 7000])
ylim([10^-23 10^-16])
```