Optimizing sensitivity of searches for continuous gravitational waves at fixed computing cost

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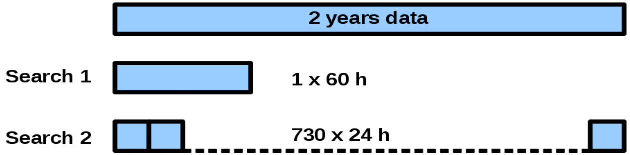
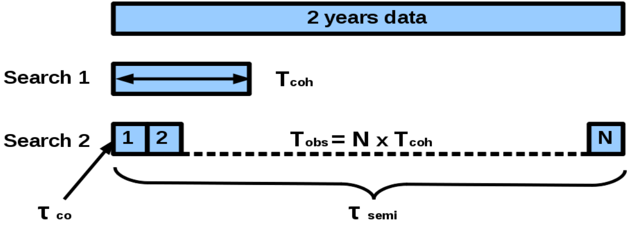
In collaboration with Reinhard Prix.

- We are interested in detection of unknown sources of continuous gravitational waves, e.g. unknown pulsars.
- To perform a search, we need to compute a matched filter ($\mathcal{F}$-statistic).
- Even simple blind search for unknown pulsars is a search over very large 4D-parameter space
$$\{f, \alpha, \delta, \dot{f}\}.$$
- Full coherent integration is computationally limited, thus semicoherent techniques should be applied (e.g. E@H).



How much data should be used to maximize the sensitivity at fixed computing cost?



- Fully coherent computing cost τ_{coh} scales with high order α of T_{coh}

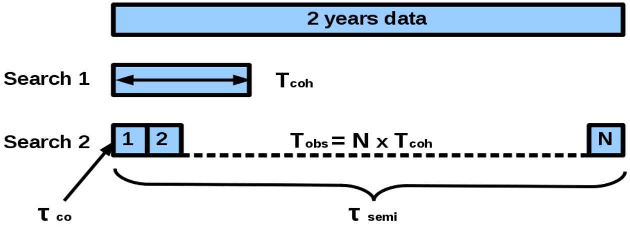
$$\tau_{coh} = \kappa_{coh} T_{coh}^{\alpha}.$$

- Computing cost τ_{semi} to combine N segments

$$\tau_{semi} = N(N\kappa_{semi} T_{coh}^{\beta}).$$

- Total computing time for N segments

$$\tau = N\tau_{coh} + \tau_{semi}$$



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For E@H S5R5:

$$\alpha = 6$$

$$\beta = 5$$

$$\kappa_{coh} = 3.1 \times 10^{-26}$$

$$\kappa_{semi} = 1.8 \times 10^{-21}$$

- Sensitivity of a search

$$h_0 = C S_n^{1/2} \frac{1}{\sqrt{T_{coh} N^{1/2}}},$$

where h_0 is the minimal measurable strain for given false-alarm and false-dismissal.

- Minimize under the restriction

$$\tau = N\tau_{coh} + \tau_{semi},$$

with $\tau_{coh} = \kappa_{coh} T_{coh}^{\alpha}$,$\tau_{semi} = N(N\kappa_{semi} T_{coh}^{\beta})$ and $N = \frac{T_{obs}}{T_{coh}}$.

$$h_0 = C S_n^{1/2} \frac{1}{\sqrt{T_{coh} N^{1/2}}} \ , \ \tau = N\tau_{coh} + \tau_{semi} \ , \ \tau_{coh} = \kappa_{coh} T_{coh}^{\alpha} \ , \ \tau_{semi} = N(N \kappa_{semi} T_{coh}^{\beta})$$

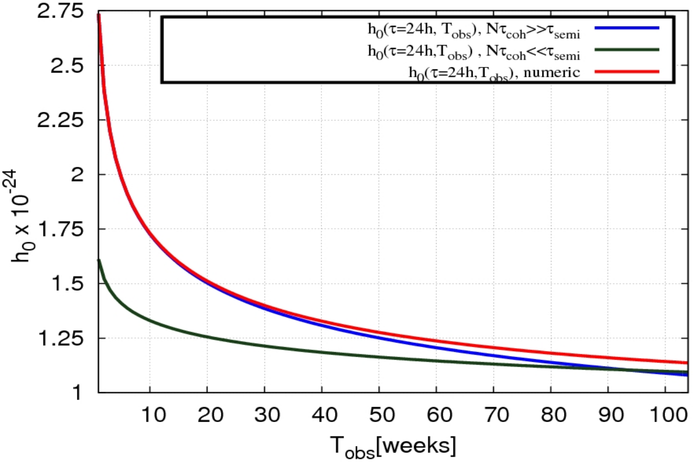
- It is very instructive to find analytical solution for h_0 as function of τ and T_{obs}
- $N\tau_{coh} \gg \tau_{semi}$ - the total computing cost is determined by the cost of the N coherent steps

$$h_0(\tau, T_{obs}) = C S_n^{1/2} \left(\frac{\tau}{\kappa_{coh}}\right)^{-1/20} T_{obs}{}^{-1/5}.$$

- $N\tau_{coh} \ll \tau_{semi}$ - the total computing cost is determined by the cost of the semicoherent combination of N

$$h_0(\tau, T_{obs}) = C S_n^{1/2} \left(\frac{\tau}{\kappa_{semi}}\right)^{-1/12} T_{obs}{}^{-1/12}.$$

- critical condition $\boxed{\frac{\delta - 2\gamma}{\delta - \gamma} > 0}$, with γ order of N and δ order of T_{obs}.



- h_0 is a monotonically decreasing function of T_{obs}.
- To achieve maximum sensitivity in a semicoherent search at fixed computing cost, all of the available data should be used.
- We would like to optimize the follow-up search of E@H outliers.

Optimize your search with respect to the critical condition and use all your data!

Thank you!