CW *Sensitivity depth*

What amplitudes h_0 are/will-be detectable?

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Search sensitivity & estimation pitfalls

Sensitivity $\equiv$ smallest CW amplitude $h_0\big|^{p_{\mathrm{det}}}_{p_{\mathrm{fa}}}$

. . . detectable with probability p_{det} (typically 90% or 95%) at a false-alarm level of p_{fa} (say 1%, "5-sigma",. . .).

First sensitivity estimate: (targeted J1939+2131 in LIGO S1) [LSC, PRD69(2004)]

$$h_0(f)\big|^{p_{\mathrm{det}}=90\%}_{p_{\mathrm{fa}}=1\%} \approx 11.4\sqrt{\frac{S_{\mathrm{n}}(f)}{T_{\mathrm{data}}}}$$

$S_{\mathrm{n}}(f)$: single-sided noise PSD at frequency f, T_{data}: total amount of data used

Caveats:

- fully coherent search
- single template (no template-bank mismatch!)
- slightly biased & neglects sky-position (error $\lesssim +20\%$)

☞ only use for coherent single-template searches ✗

Search sensitivity: more pitfalls

Semi-coherent analytic estimate:

$$h_0\big|_{1\%}^{90\%} \approx (7-9)\, N_{\mathrm{seg}}^{1/4} \sqrt{\frac{S_{\mathrm{n}}(f)}{T_{\mathrm{data}}}}$$

More caveats:

- $N_{\mathrm{seg}}^{1/4}$ scaling only holds for $N_{\mathrm{seg}} \gtrsim \mathcal{O}(100-1000)$
- biased estimate ($\sim +30\%$)
- must adjust for search mismatch & false-alarm p_{fa}!

bias: S5 E@H all-sky search ☞ would over-estimate by $\times 2$!

Accurate estimation framework: [Wette PRD85(2012)], [Dreissigacker,Prix,Wette, PRD98(2018)]

with Octave [OctApps] and Python [Cows3] implementations

BUT ☞ requires template-bank mismatch (average or dist), realistic estimate of p_{fa} used, full understanding of hierarchical+semi-coherent search setup details . . .

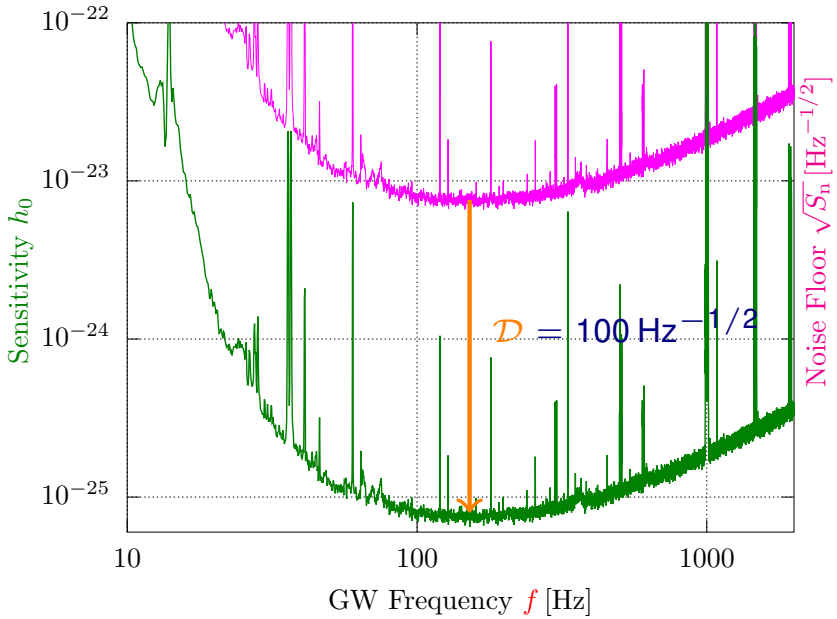
☞ recommended only for "expert" use cases ✗

Sensitivity Depth $\mathcal{D}$

CW sensitivity $h_0(f)$ factors as

$$h_0(f) = \frac{\sqrt{S_n(f)}}{\mathcal{D}}$$

fixed search setup ☞ *constant* $\mathcal{D}$



☞ $\mathcal{D}$ characterizes the search setup independently of $S_n(f)$

Why is this useful? Extrapolate future sensitivity:

Same search setup applied to future data ☞ $\approx$ same $\mathcal{D}$

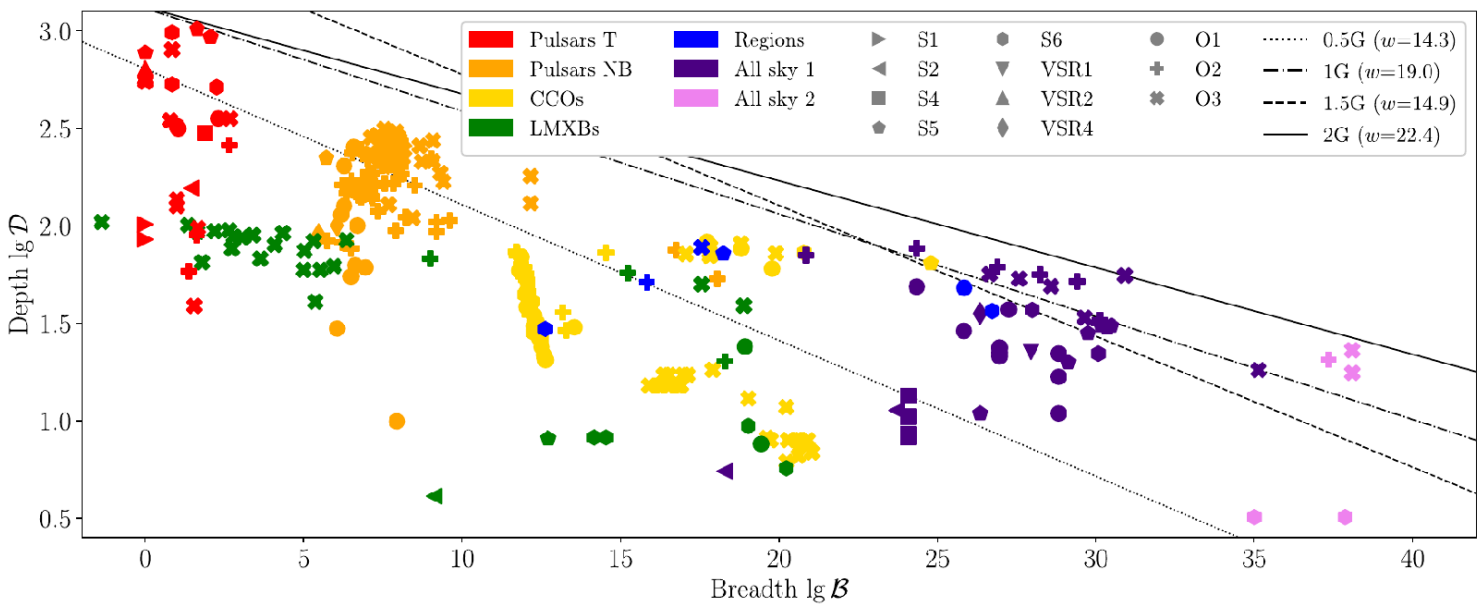
How to obtain:

- often provided explicitly with search results,
- or look up here: Wette, APP153(2023) ☞ 297 searches up to July 2023,
- or estimate from ULs: $\mathcal{D} \equiv \sqrt{S_n(f)}/h_0(f)$

Typical current sensitivity depths

parameter-space size

- Targeted searches (fully coherent): $\mathcal{D} \sim \frac{\sqrt{T_{\text{data}}}}{11.4}$
  - 2 years $\times$ 2 detectors: $\mathcal{D} \sim 1000\,\text{Hz}^{-1/2}$
  - O1: 78+66 days: $\mathcal{D} \sim 300\,\text{Hz}^{-1/2}$
- Directed searches (Galactic center, Cas-A, Sco-X1)
  ☞ $\mathcal{D} \sim 70 - 110\,\text{Hz}^{-1/2}$
- All-sky searches for *isolated* NSs
  ☞ $\mathcal{D} \sim 30 - 60\,\text{Hz}^{-1/2}$
- All-sky *binary* search
  ☞ $\mathcal{D} \sim 17 - 38\,\text{Hz}^{-1/2}$



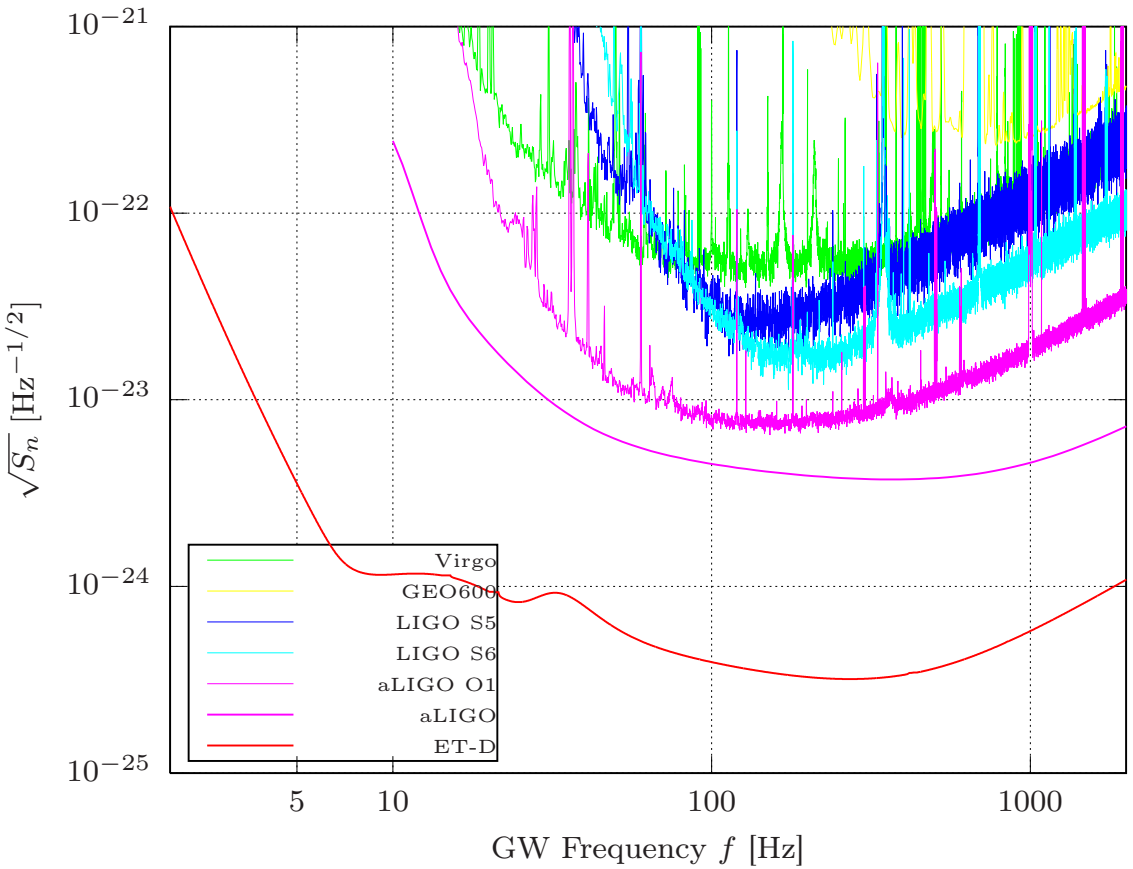
[Wette, APP153(2023)]

What future sensitivity improvements can we expect?

Sensitivity gains can come from 3 factors:

1. more sensitive detectors $\sqrt{S_{\mathrm{n}}}$
2. more computing power C (e.g., Moore's law) ☞ $\mathcal{D} \sim C^{1/10}$

   [Prix,Shaltev PRD85(2012)]
3. better/more efficient *search methods* ☞ $+(30-50)\%$?



- aLIGO design
- ET/CE