Proposed Control Room Figures of Merit for Pulsar Sensitivity

Keith Riles
(University of Michigan)

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DMT Infrastructure to Exploit

- Real-time access to online data
- Graphical display:
  - Time histories (strip charts)
  - Spectral plots
- Web page summaries and plots
- Trend file output of selected FOM values
- Monitoring of the monitor

Proposed FOM's based on ideas

suggested by pulsar group members

Pulsar Figure of Merit 1

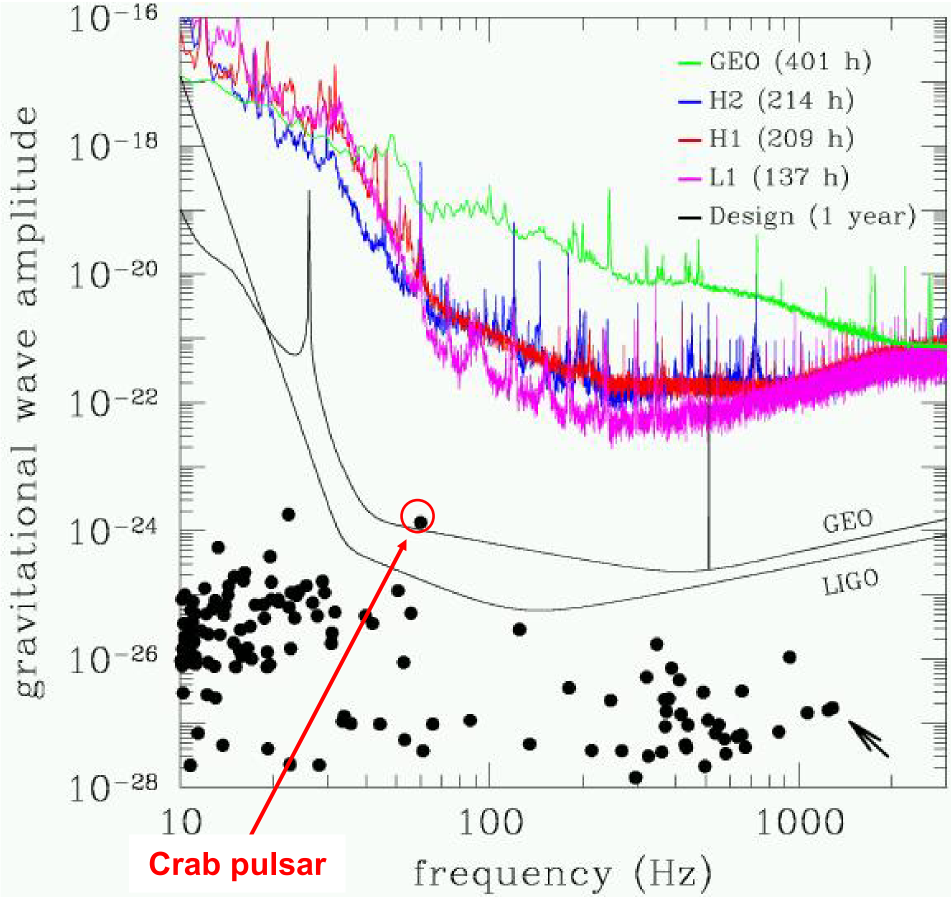
Strain sensitivity – Fixed time intervals

- Rescaled power spectral density for observation time T:

$$< h_0 > \quad = \quad 11.4\sqrt{S_n(f_s)/T}$$

- Display $<h_0(f_s)>$ over f_s = 10-2000 Hz for time intervals:
    - 1 day
    - Length of data run (e.g., 70 days for S3) ← Primary FOM1
    - 1 year
- Result: pulsar-relevant PSD (no change in shape)

Pulsar Figure of Merit 1 (cont.)



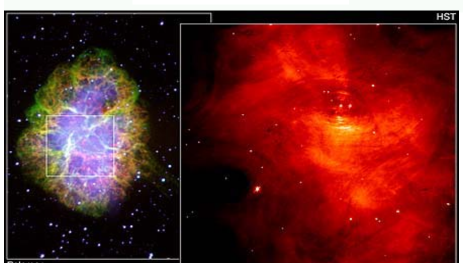


Figure 1 from
S1 pulsar paper

Colored curves for actual S1 T_{obs} values

Black curves for 1 year at design

Dots are energy conservation limits on known pulsars

Pulsar Figure of Merit 2

Time needed to meet energy conservation limit for known pulsars

• For pulsar with $f_s = 2f_{rot}$, spin-down dP/dt, moment of inertia I, and at distance r, energy conservation requires:
(assuming all energy loss due to gravitational waves!)

$$h_{EC} = \frac{5.7 \times 10^{-24}}{[r/(1kpc)]} \sqrt{\left(\frac{f_s}{1\,\mathrm{kHz}}\right)\left(\frac{\dot{P}}{10^{-13} s/s}\right)\left(\frac{I}{10^{45} g \cdot cm^2}\right)}$$

• Observation time required to attain sensitivity to h_{EC}:

$$T = \frac{(11.4)^2 S_n(f_s)}{h_{EC}^2}$$

Pulsar Figure of Merit 2 (cont.)

For reference, at LIGO I design at ~60 Hz [~10^{-22} / sqrt(Hz)], testing energy conservation for the Crab requires T_{EC} ~ 9 days

Display an instantaneous frequencies series with T_{EC} vs f_s for discrete, known pulsars.

Provide summary web table of instantaneous T_{EC} values and recent averages

For selected pulsars, display time history of T_{EC} and write trend

Example: 12-hour strip chart of Crab T_{EC} (weeks) ← Primary FOM2

Astrophysically interesting

Experimentally challenging in the extreme: f_s ~ 59.93 Hz

Pulsar Figure of Merit 3

Ellipticity sensitivity – known and unknown pulsars

- For known pulsars, FOM1 converts to a pulsar ellipticity sensitivity:

$$<\epsilon> = (9.5\times10^{-6}) \left[\frac{r}{\mathrm{kpc}}\right] \left[\frac{f_s}{\mathrm{kHz}}\right]^{-2} \left[\frac{I}{10^{45}\mathrm{g}\cdot\mathrm{cm}^2}\right]^{-1} \left[\frac{<h_0>}{10^{-23}}\right]$$

- Display graph and html table of <ε> for known pulsars for same time intervals as in FOM1 (e.g., 1 day, run duration, 1 year)

- Display generic curves of <ε> vs f_s for same time intervals assuming pulsar at fixed distance of 1 kpc (adds $1/f_s^2$ weight to PSD)

Primary FOM3: Graph of <ε> for known pulsars for run duration

Pulsar Figure of Merit 4

Cumulative actual sensitivity

- At start of data run, monitor starts accumulating ideal sensitivities, using

$$< h_0(f_s) > = 11.4\ [< S_h >_{\mathrm{cumulative}}]^{1/2}$$

Where $<S_h(f_s)>_{\mathrm{cumulative}}$ is the cumulative weighted average of $<S_h>$

- Display graph (smooth curve vs f_s)
- Display html table for known pulsars of cumulative values and energy-conservation limits

Pulsar Figure of Merit 4 (cont.)

Remarks:

- Useful for performance evaluation
- But not useful for real-time feedback
- Patrick warns me that history retention and keeping track of science mode vs common mode are painful
- Would not include as a primary FOM
- Lowest-priority FOM to implement

Summary

Three "primary" FOM's for (reasonably) prominent display:

(FOM1) Pulsar strain sensitivity for (T_{obs} = data run)

(FOM2) Time (weeks) to reach energy conservation limit for Crab

(FOM3) Ellipticity sensitivity to known pulsars (T_{obs} = data run)

We have a volunteer! -- Greg Mendell