

"Thoughts on Scientific Context & Aims
for LIGO R&D"

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LIGO-G980113-09-M

SOURCE-BASED "METRICS" FOR JUDGING RELATIVE MERIT OF DETECTOR IMPROVEMENTS

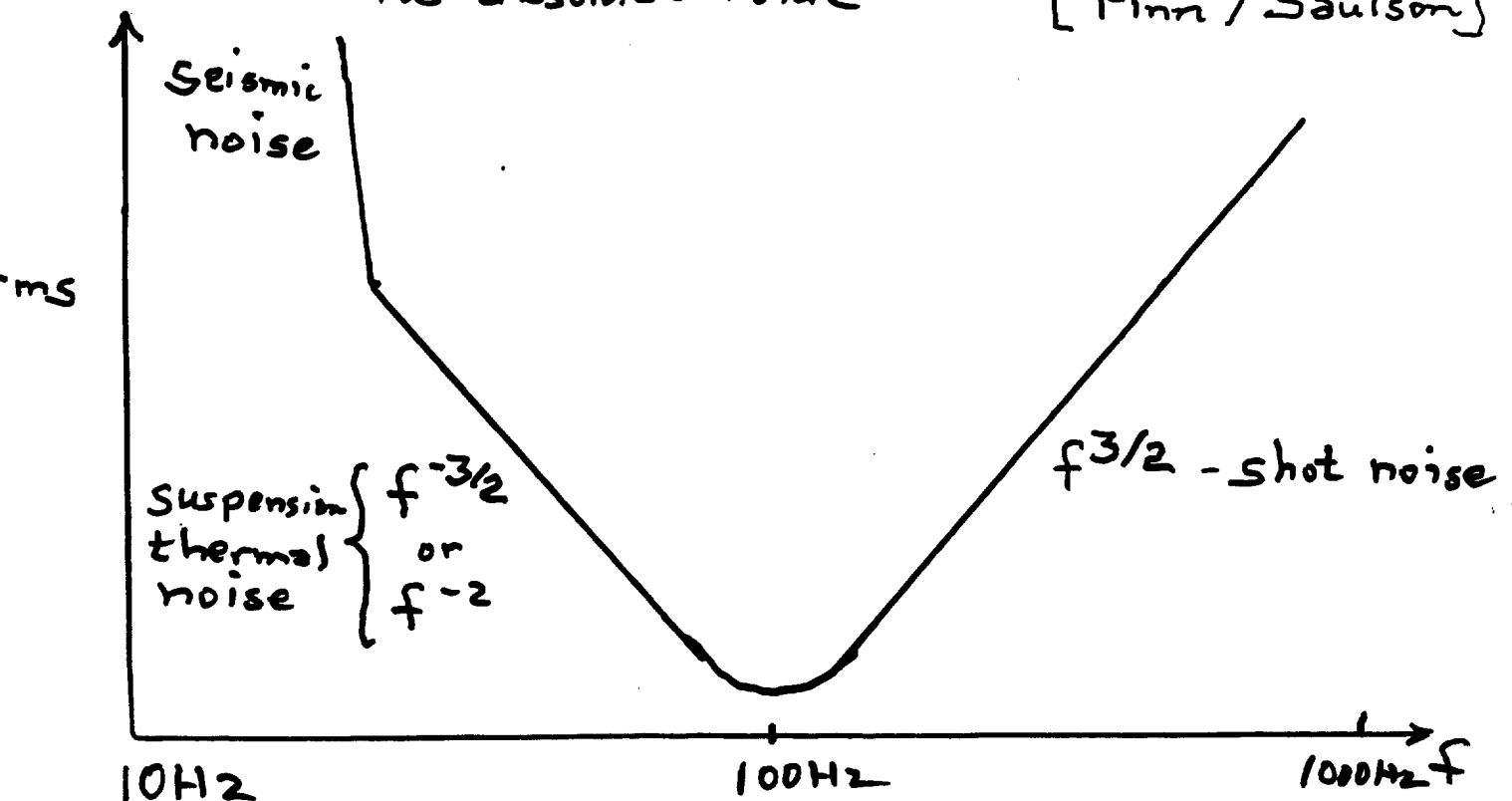
$$\left(\frac{S}{N}\right)^2 = 4 \int_0^{\infty} \frac{|\tilde{h}_{sig}|^2 df}{S_h(f)} = \int_{-\infty}^{+\infty} \left[\frac{h_{sig}^{rms}(f)}{h_{noise}^{rms}(f)} \right]^2 d \ln f$$

$$h_{sig}^{rms}(f) = 2 |\tilde{h}_{sig}| f \approx h_{sig} \sqrt{f}$$

- shape fairly well understood
- event rate per unit volume badly understood
- For each source: Pick arbitrary distance (arbitrary amplitude of $h_{sig}^{rms}(f)$)

$$h_{noise}^{rms}(f) = \sqrt{S_h \cdot f}$$

- Vary the possible improvements... & thus $h_{noise}^{rms}(f)$
- Maximize $(S/N)^2$... pay no attention to its absolute value [Finn / Saulson]



Binary Inspiral (NS/NS, NS/BH, BH/BH): $h_{rms}^{sig} \propto f^{-1}$

BH/BH Merger & Ringdown

- Different Sources @ same distance: $h_{rms}^{sig} \propto M \propto f^{-1}$

Spinning Neutron Star:

• Sco X-1 [$h = 3 \times 10^{-26}$ @ $f \approx 500$ Hz; $h_{rms}^{sig} = h \sqrt{f \tilde{\epsilon}}$]

... other LMXB's, QPO's: $f \approx 500-750$ Hz; lower h

∴ Pulsars, fixed ellipticities, all at same distance

$$h_{rms}^{sig} \approx h \sqrt{f \tilde{\epsilon}} = \frac{2\ddot{Q}}{r} \sqrt{f \tilde{\epsilon}} \propto f^{+5/2}$$

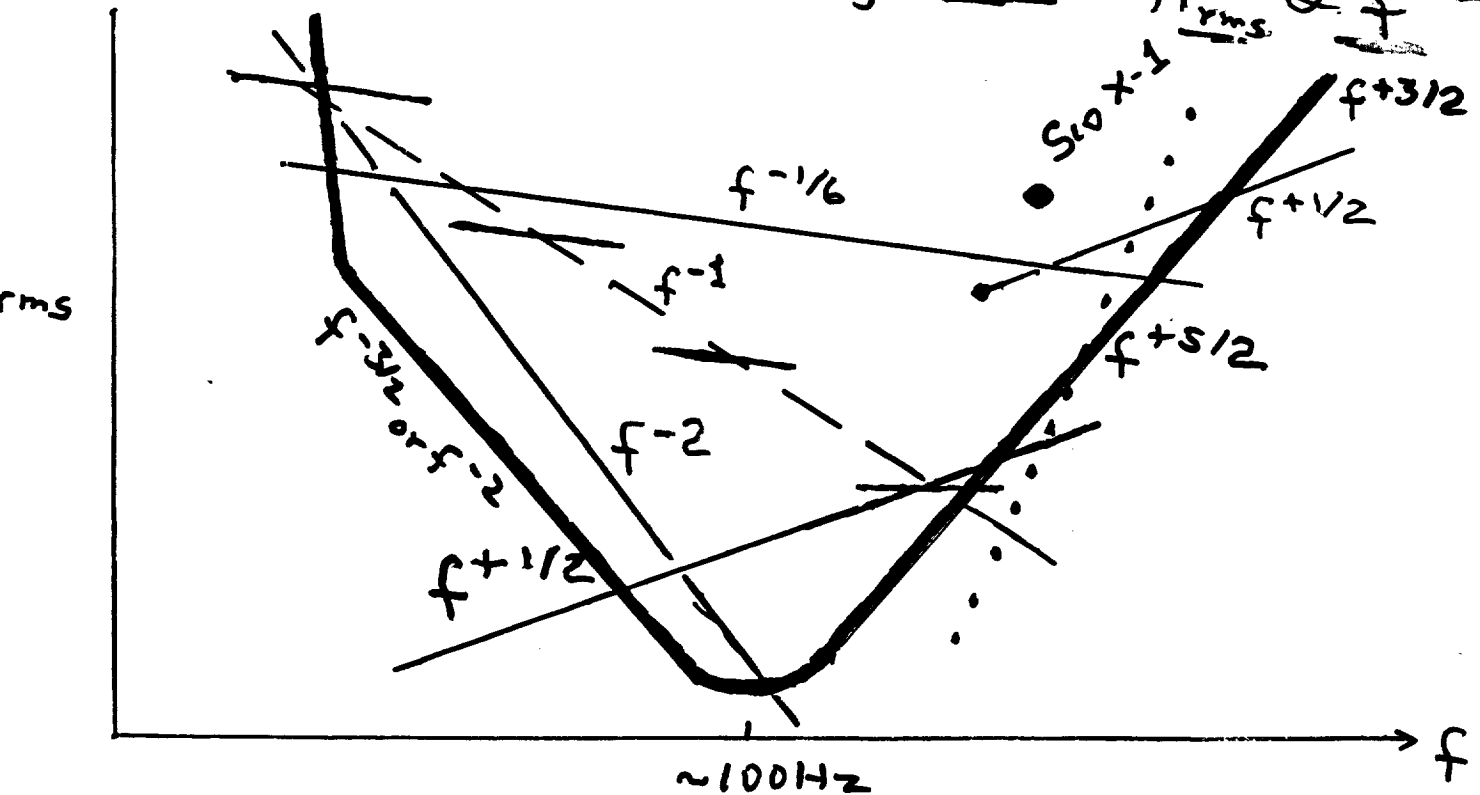
R Mode of a Newborn, Fast Spinning NS:

$$h_{rms}^{sig} \propto f^{1/2} \text{ @ } f > f_{min} \sim 300 \text{ Hz ?}$$

Non axisymmetric Supernovae: 100 km: $h_{rms}^{sig} \propto f^{-1/6}$

20 km: $h_{rms}^{sig} \propto f^{+1/2}$

Stochastic Background, $\Omega_{gw} \approx \text{const}$: $h_{rms}^{sig} \propto f^{-2}$



Kip's Personal, Tentative Conclusions

Priorities:

1. Push down lowest point of noise curve
2. Improve high-frequency performance
($f > 100 \text{ Hz}$)... including narrow-banding
for spinning neutron stars; broadening
minimum via signal recycling.
3. Push seismic wall down below $\sim 30 \text{ Hz}$
(below the "uncover a decade of thermal
noise level")

Kip's Gut Feeling - Based on all we know about sources, and allowance for our ignorance (unknown sources)

LIGO-II-2004: SQL for 11 kg test mass

- Is at a sensitivity where

$$\frac{d(\text{Probability of first detection})}{d(\text{Sensitivity})}$$

is near its maximum

- Probability of first detection is not $\sim 90\%$

→ Be more ambitious for LIGO-II
SQL for 30 kg? 50 kg?

→ reach $> 90\%$ probability of detection,
Need LIGO-III:

1992 LIGO Science Article - "Advanced" Detector
SQL for 300 kg

Must prepare for having to do this well.

Note 1, Linda Turner, 08/20/98 11:25:08 AM
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