Toward an SGWB search with the co-located LIGO detectors at Hanford

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To What End?

- Due to the overlap reduction function:
  - H1-H2 can theoretically make a 10x deeper SGWB search than H1-L1 (current H1-L1 error bar: $\sigma_\Omega \approx 4 \times 10^{-6}$, for h_{100}=0.72)
  - H1-H2 is sensitive to high frequencies (S4 H1-H2 was ~50x more sensitive than S4 L1-A1)
- The same arguments apply to the planned LCGT co-located interferometers

Our Tools

- We have two complementary techniques to identify non-gravitational contributions to H1-H2 cross-correlation:

IFO-PEM Coherence*:
Look at linear environmental couplings

IFO-IFO Timeshift†:
Look at all narrow-band signals

* Class. Quantum Grav. 23 (2006) S693-S704
† Milivoje Lukic and Vuk Mandic; unreviewed

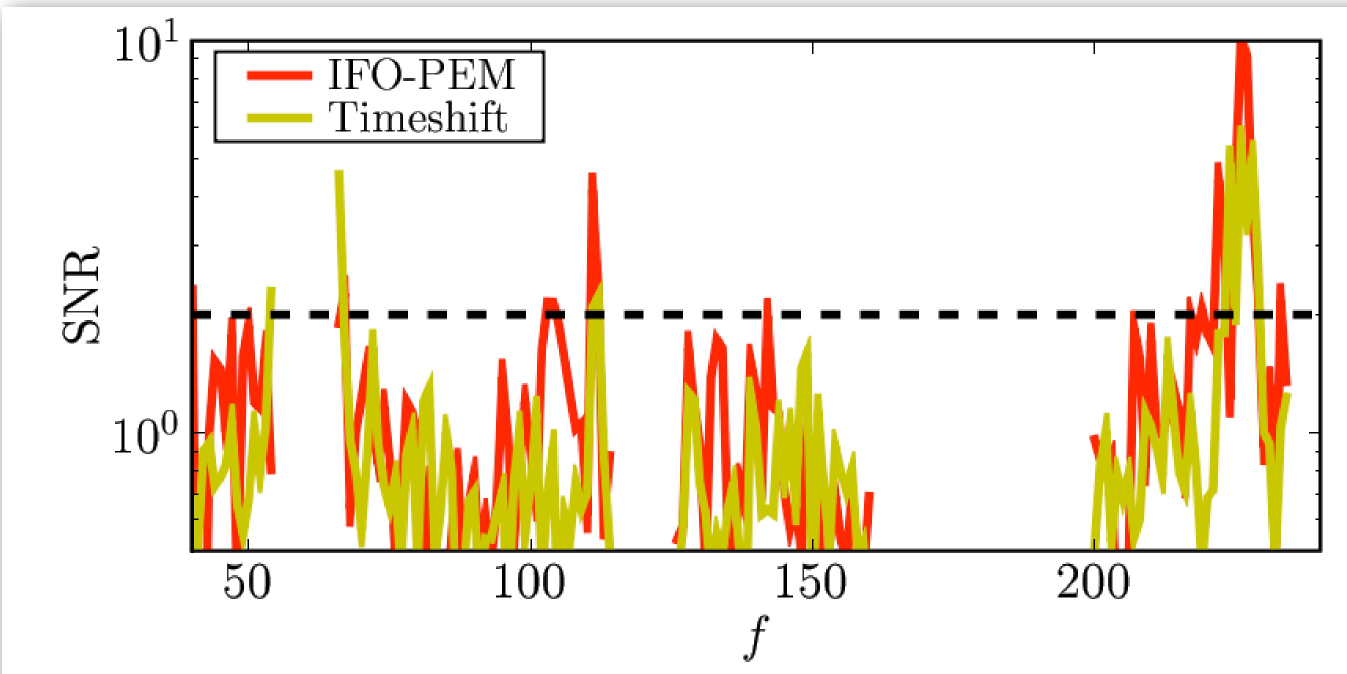
The Method

- **Veto** the egregiously bad frequencies
- **Run** the SGWB search on remaining frequencies
- **Subtract** the Ω_{PEM} estimated from this band
- **Estimate uncertainty**

Veto (I)

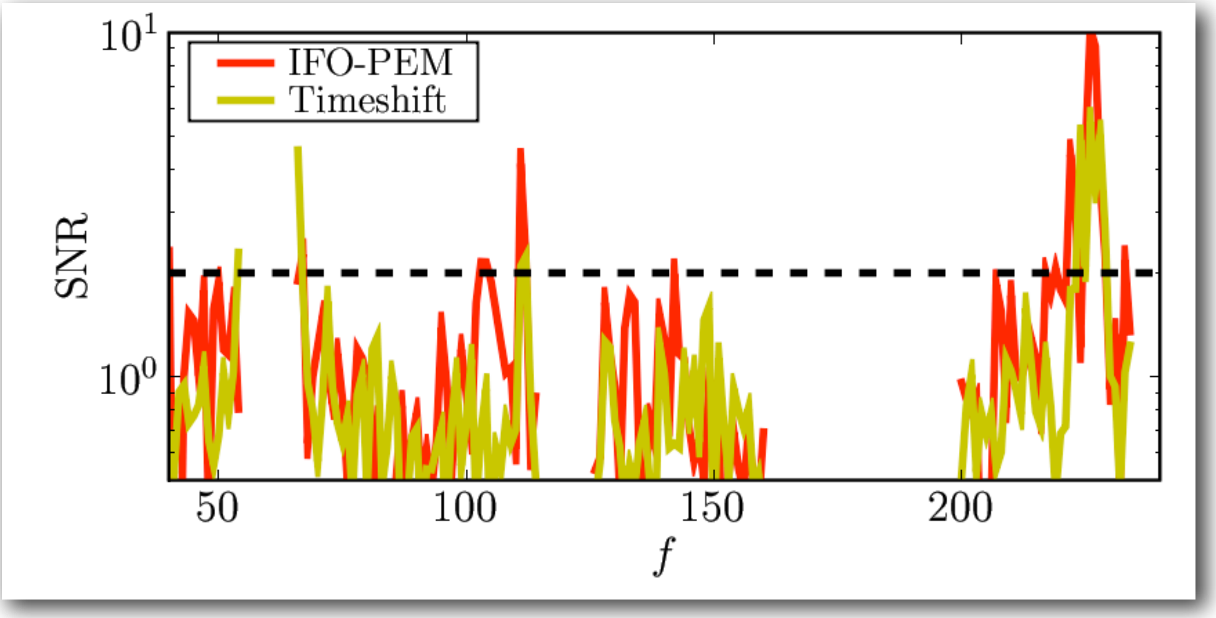
Units of: $$\mathrm{SNR} \equiv \frac{Y(f)}{\sigma(f)}$$

- Data set: a few months in early S5



Veto (II)

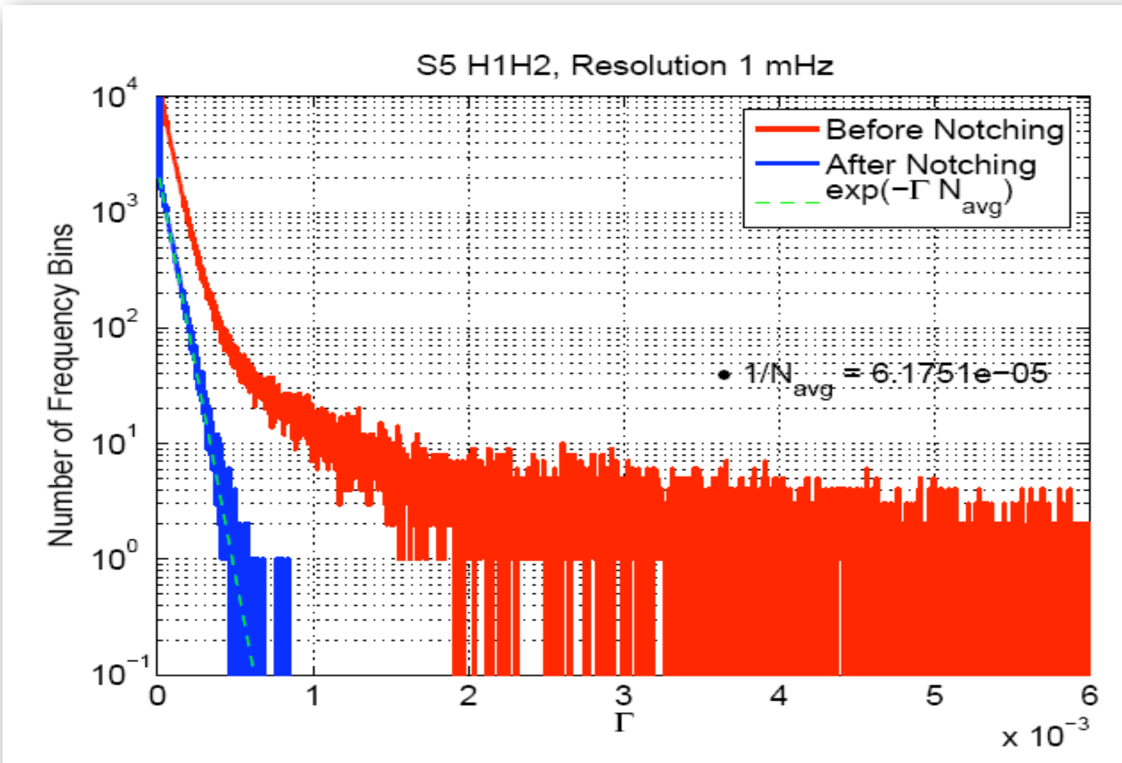
- Start with 40-240 Hz
- Notch 60 Hz harmonics
- Threshold



- Most of the regions 68-102 Hz and 126-160 Hz are preserved.

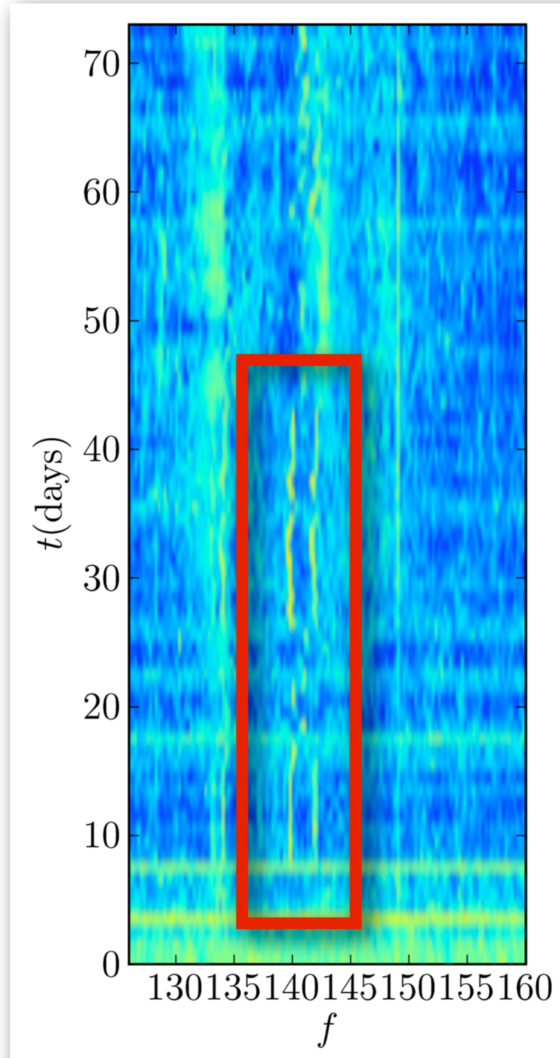
Run (I): H1-H2 Coherence

- Superficially well-behaved after veto



Run (II): Non-stationarity

- Example:
  - Feature at 138-143Hz shut off fairly abruptly
  - Visible, but washed out over whole dataset
- Possible Solutions:
  - Always look at instrumental coherence estimates on multiple sub-epochs
  - Split whole search into multiple epochs with independent vetoes

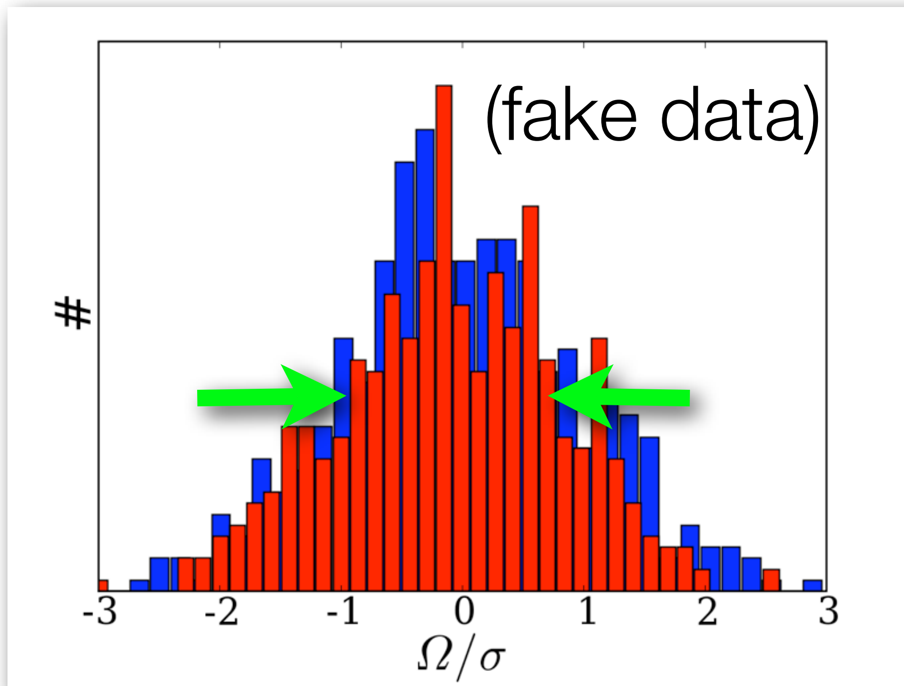


Subtract

- From IFO-PEM coherence, compute Ω_{PEM} and subtract from Ω_{naive}
- Hope to narrow distribution of significances

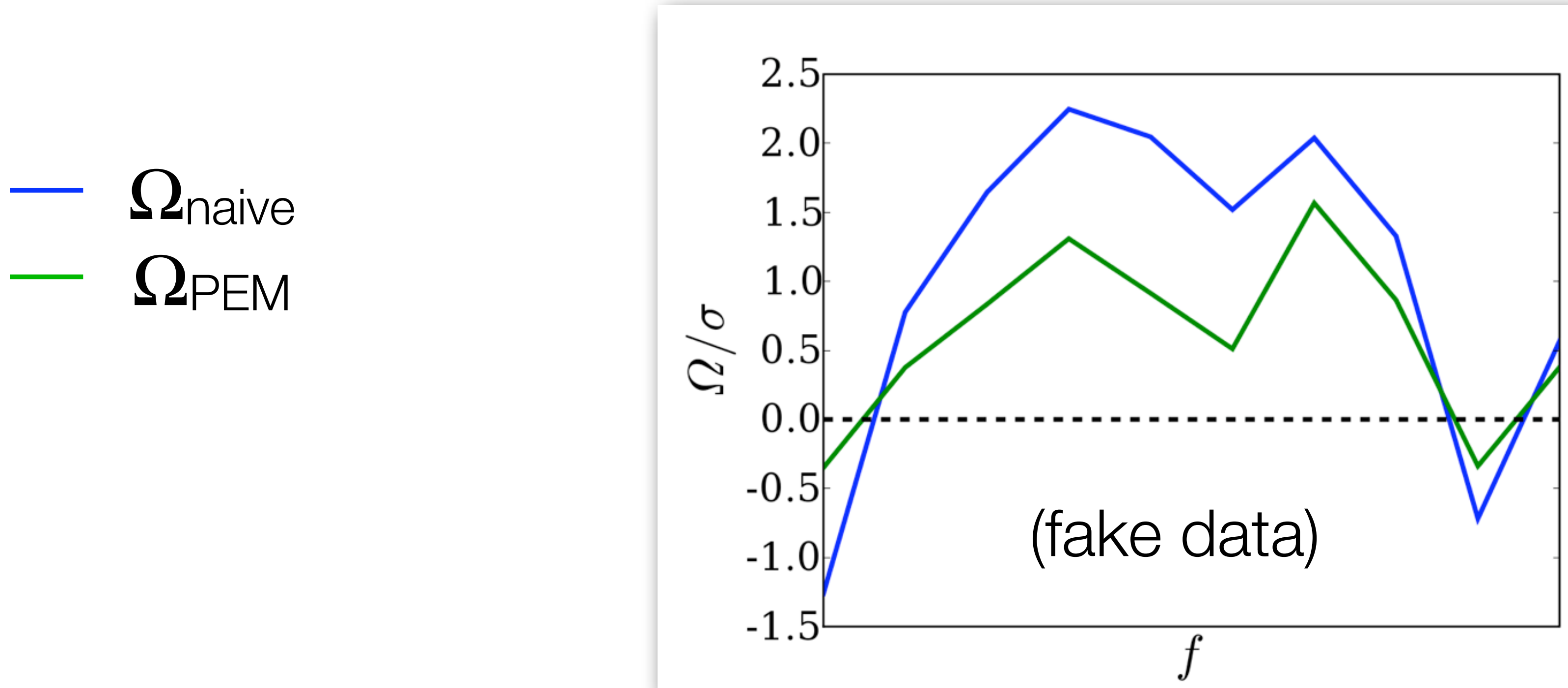
Ω_{naive}

$\Omega_{naive} - \Omega_{PEM}$



Estimate Uncertainty

- Compare Ω_{naive} to Ω_{PEM} in vetoed (i.e. environmentally dominated) frequency bands
- Can assess systematics



Closing Words

- IFO-PEM coherence and time-shift methods agree well in identifying compromised frequency bands.
- IFO-PEM coherence method also offers a way to estimate the remaining broad-band correlations, which can then be subtracted.
- PEM coverage can never be complete, leaving a residual environmental contribution, Ω_{env}, to Ω_{GW}.
  - A negative Ω_{env} can cancel a positive Ω_{GW}, giving a false null result. Can we quantify the probability of two large numbers canceling?
  - A positive Ω_{env} can give a false detection. Would we ever believe a detection with H1-H2?

Appendix: SGWB Equations

- Energy density:

$$\rho_{\mathrm{GW}} = \frac{c^2}{32\pi G}\langle \dot{h}_{ab}\dot{h}^{ab}\rangle$$

- Characterized by log-frequency spectrum:

$$\frac{1}{\rho_{\mathrm{c}}}\mathrm{d}\rho_{\mathrm{GW}} = \Omega_{\mathrm{GW}}(f)\,\mathrm{d}\ln f$$

- Related to strain power-spectrum as:

$$S(f) = \frac{3H_0^2}{10\pi^2}\frac{\Omega_{\mathrm{GW}}(f)}{f^3}$$

- Strain scale:

$$h(f) = 6.3\times 10^{-22}\sqrt{\Omega_{\mathrm{GW}}(f)}\left(\frac{100\mathrm{Hz}}{f}\right)^{3/2}\mathrm{Hz}^{-1/2}$$

Appendix: Search Equations

- Cross-correlation estimator:

$$Y(f) = \int_{-\infty}^{\infty} \tilde{s}_1^*(f)\tilde{s}_2(f)\tilde{Q}(f)\,\mathrm{d}f$$

- Theoretical variance:

$$\sigma_Y^2 \approx \frac{T}{2}\int_0^{\infty} P_1(f)P_2(f)\,|\tilde{Q}(f)|^2\,\mathrm{d}f$$

- Optimal filter:

$$\tilde{Q}(f) = \frac{1}{N}\frac{\gamma(f)\Omega_{\mathrm{t}}(f)}{f^3 P_1(f)P_2(f)}$$