Analysis of Data from Interferometric Gravitational-wave Detectors

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for

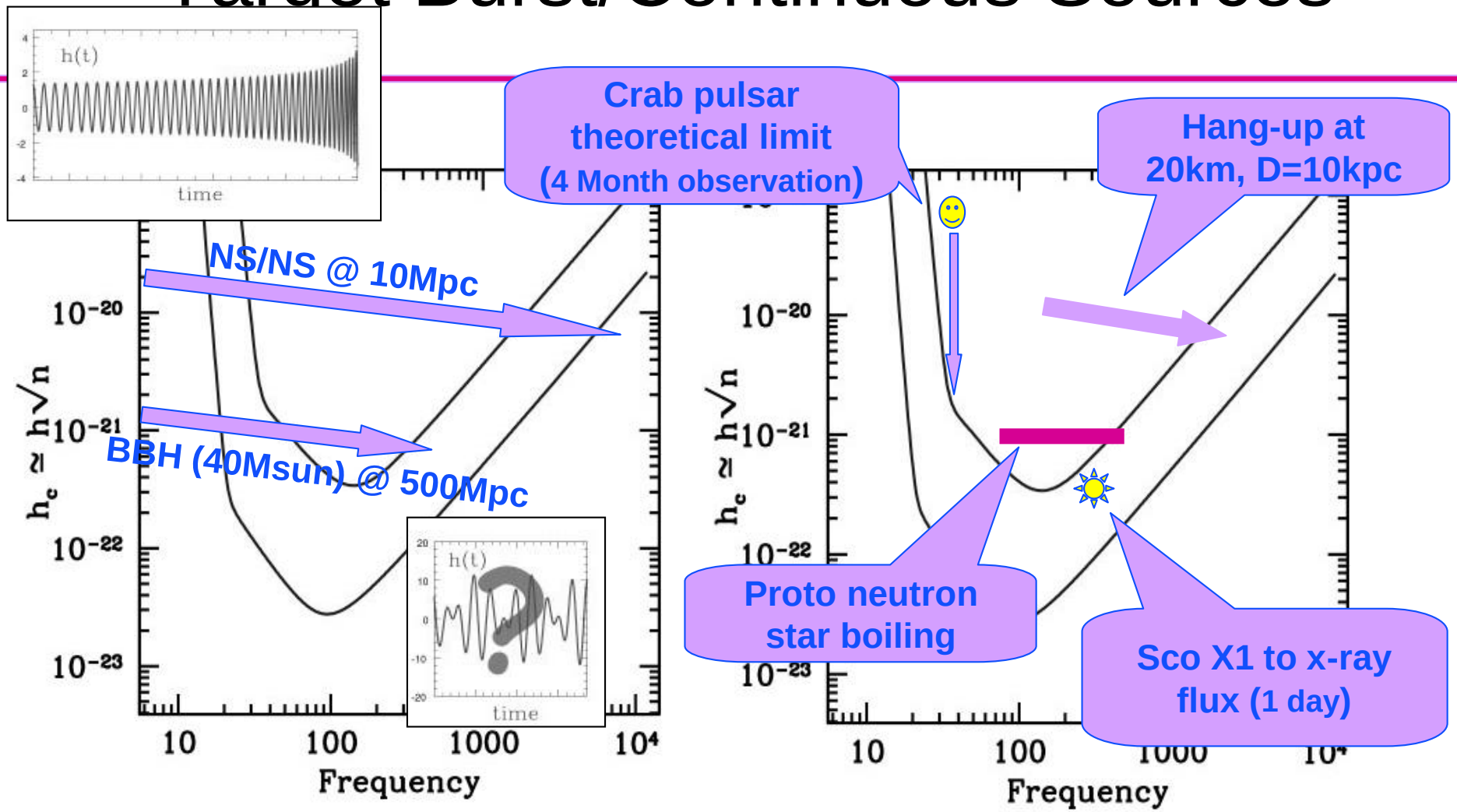
LIGO Scientific Collaboration

LIGO-G020423-00-Z

Waves and Detectors

- Gravitation
  - » Weaker than Electromagnetism
  - » Radiation from coherent motion of large bodies
  - » Weakness → difficult to detect
  - » Weakness → Universe is transparent to them
- Interferometers
  - » Inherently broadband and multi-directional
  - » Non-Gaussian noise
  - » Non-stationary
  - » Cannot shield from sources → no off-source stats

Target Burst/Continuous Sources



Detection strategies

- Coherently accumulate power from signal (when in interferometer band) into a single number
- Classic example
  - » Detection of periodic signal in noise by Fourier transform, compare output with expected power due to noise alone.

Bayesian Optimal Detectors

- Weinstein & Zubakov, Finn, Finn & Chernoff

$$p(s \mid h)$$

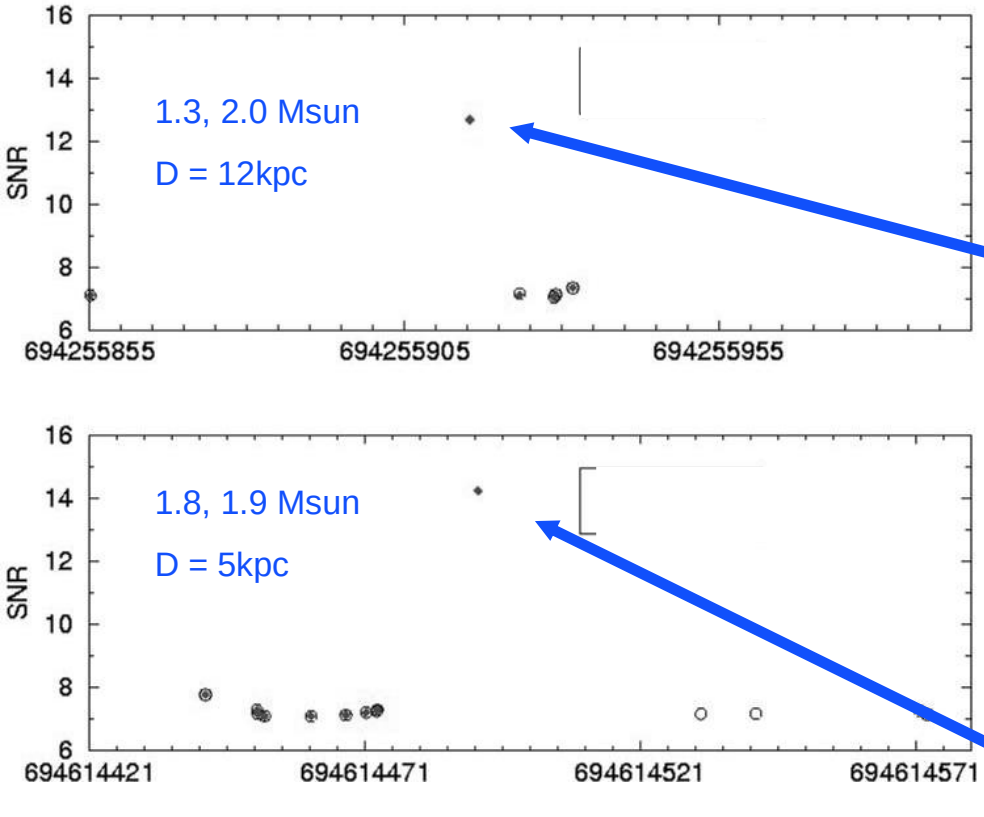
Depends monotonically on

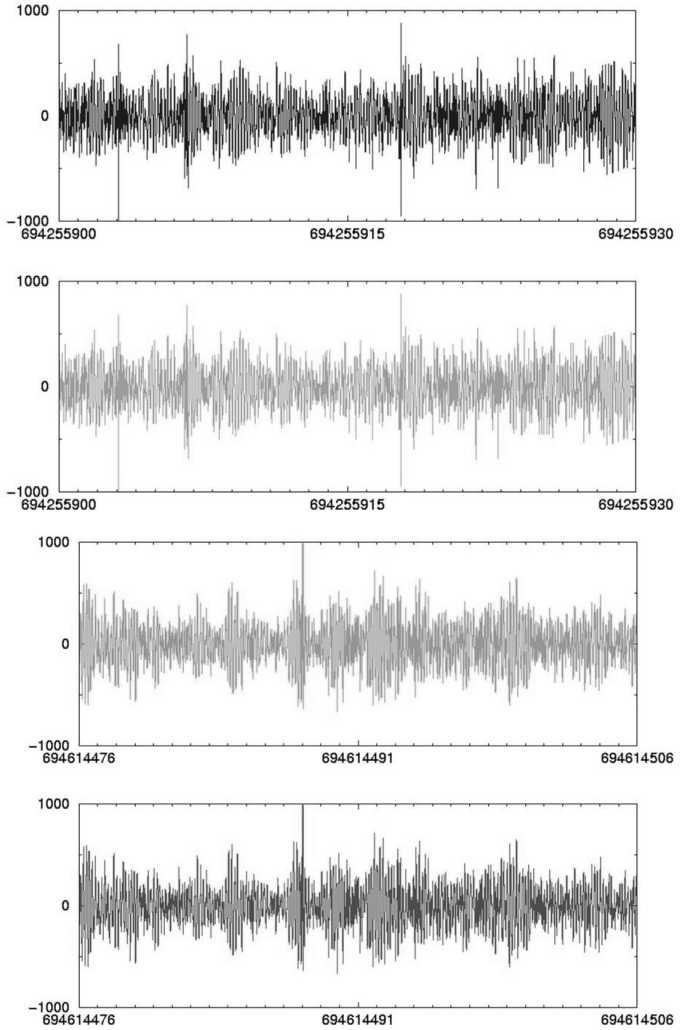
$$\int d\lambda \left(\frac{p(h|s)}{p(h|0)} \, p[s \mid \lambda] p[\lambda] \right)$$

- For Gaussian noise and known signal, this gives matched filtering

$$\sum_{k=0}^{N-1} \tilde{s}_k^* \tilde{h}_k / S(f_k)$$

Testing Detection Methods in Real LIGO (E7) Noise





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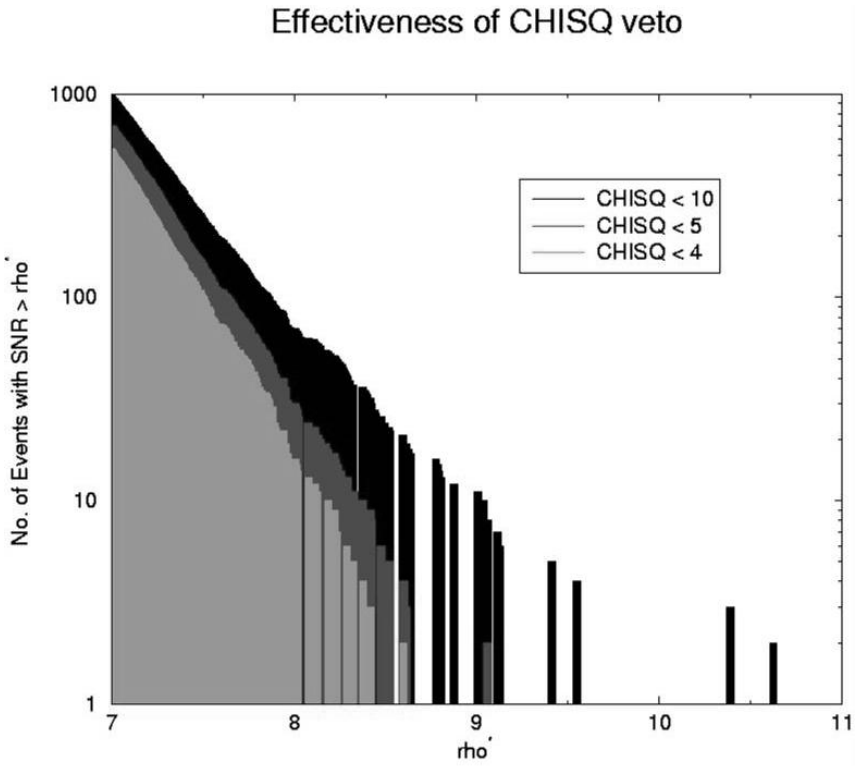
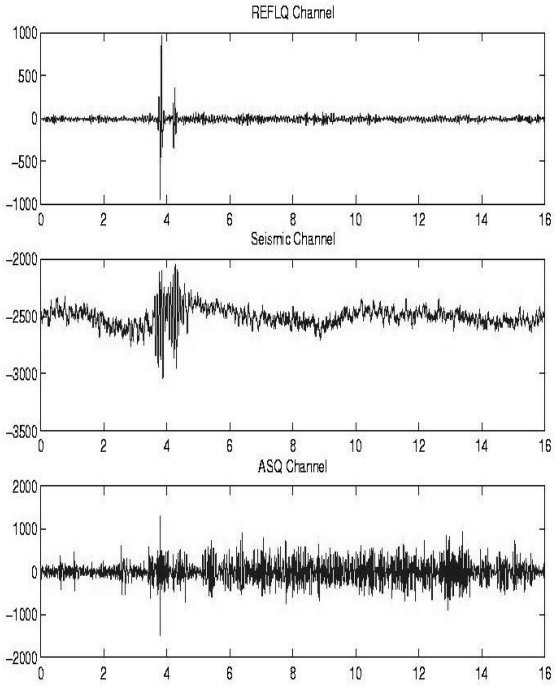
Dealing with non-Gaussian Noise



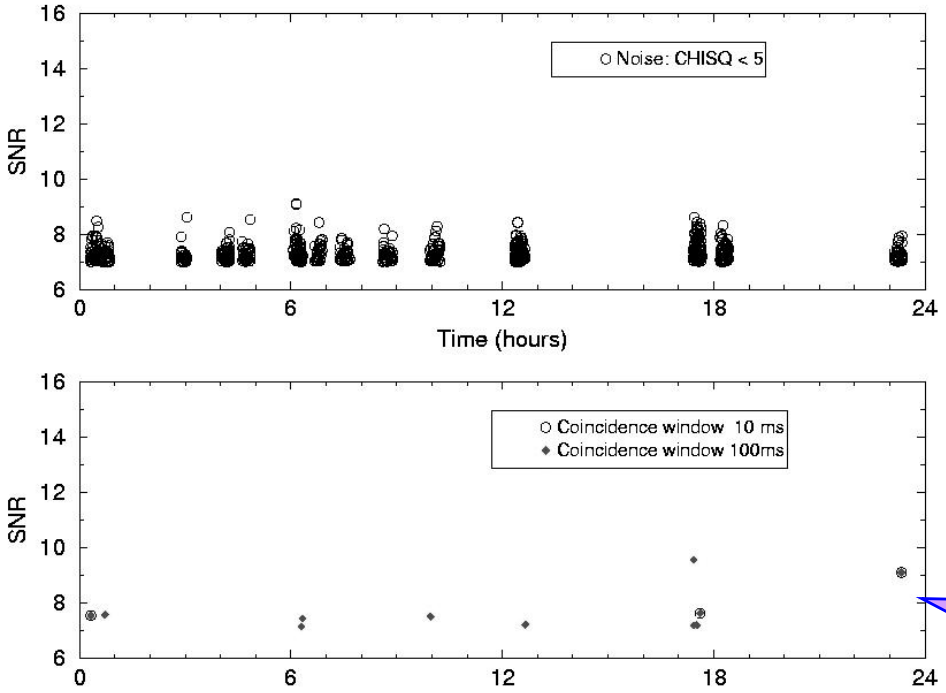
- Many mechanisms
- How to deal with them?
  - » Signal based veto: does SNR accumulate as expected?
  - » Originally proposed by Allen, implemented here by Anderson, Brown, and Creighton

Non-Gaussian Spurions



- Example:
  - » Cattle Guard at LIGO Livingston (**Gonzalez, Chickarmane, Saulson during E7)**
- How to deal with them?
  - » Auxiliary channels: does spurion show up in other channels?
  - » Coincidence: does signal show up in multiple instruments with appropriate parameters?

Non-Gaussian Spurions



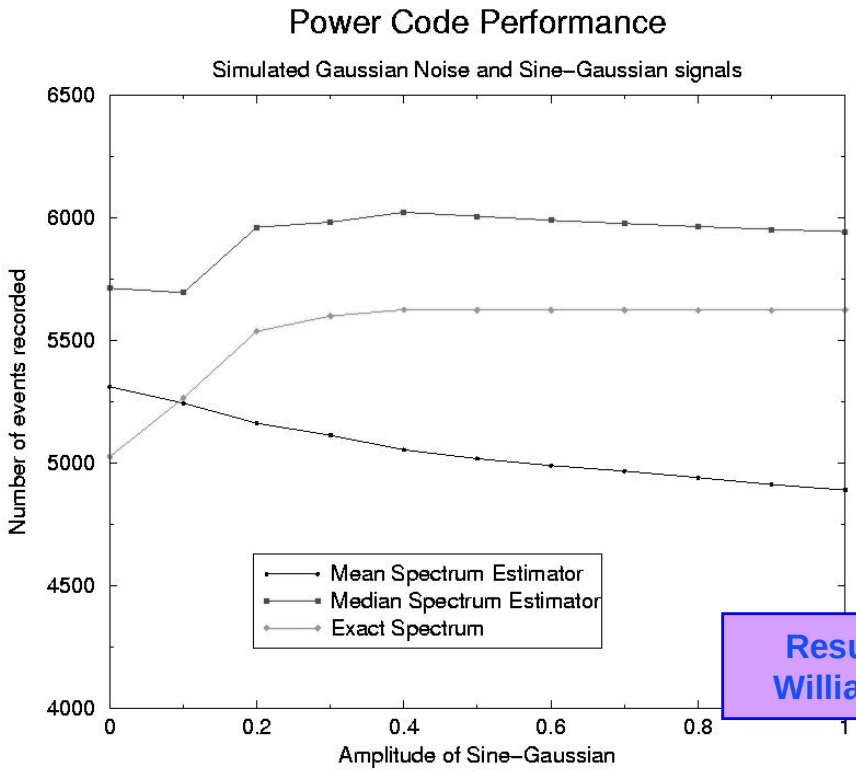
- How to deal with them?
  - » Coincidence: does signal show up i multiple instruments with ``same'' parameters?

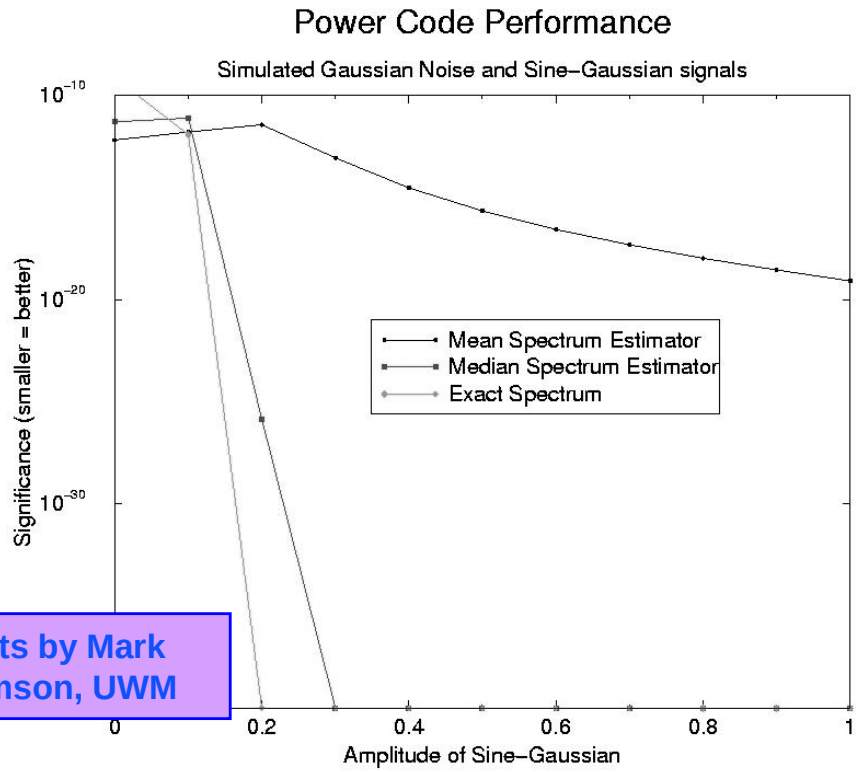
All candidates vetoed by signal strength consistency

Non-stationarity

- Instruments are not perfectly stationary
- How to deal with this in data analysis
- First order, notice that search algorithms depend on $\tilde{h}(f)/\sqrt{S(|f|)}$
- Need robust estimator for power spectrum S(|f|) which
  - » Tracks no -stationarity
  - » Is not biased by non-Gaussian bursts

Mean versus Median Estimators





Results by Mark Williamson, UWM

Concluding Remarks

- Best detection algorithms rely on having some knowledge of expected signals
- Experience is being gained by scientists working with real interferometric data.
- Non-stationarity and non-Gaussianity require supplementing standard algorithms with veto methods
- Inability to go off-source provide interesting difficulties similar to bar detectors
- First analysis results should be available soon