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# Long-duration Hardware Injections of Stochastic signals in E10 / S3

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# Motivation for hardware injections of stochastic signals

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- *Test the complete pipeline*, from the actuation of the test masses to the detection of the signal via the use of calibration functions
- The stochastic analysis is *inherently a coherent network detection*. Signal retrieval tests our understanding of multi-detector systematics including (esp., *those that evade detection in SW injections*):
  - » Presence of cross-correlated detector noise
  - » Calibration inaccuracies
- *Long-duration*: Real test of the assumption implicit in search analysis that *signal is weaker than the noise*



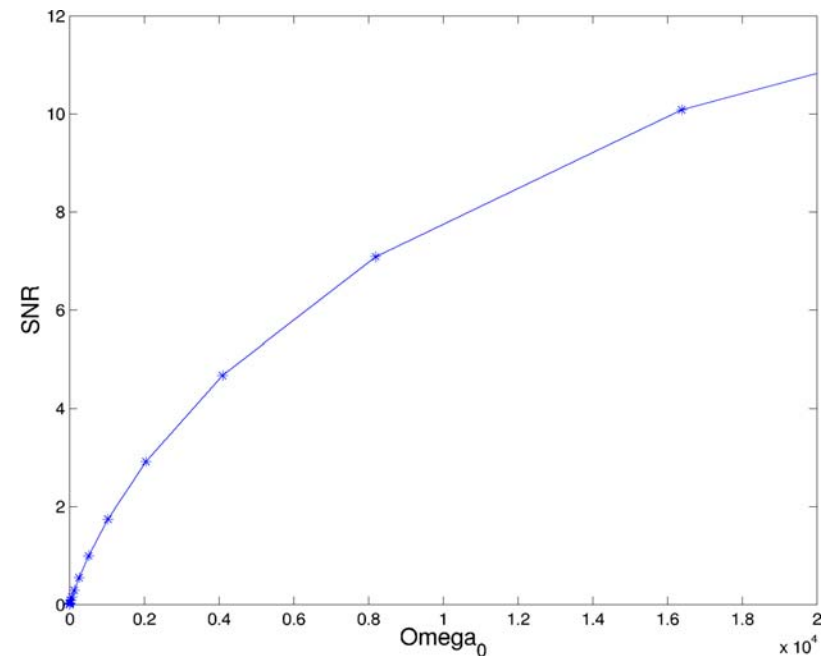
# The problem with short-duration injections

For weak signals:

$$\text{SNR} \approx \frac{3H_0^2\Omega_0}{10\pi^2} \sqrt{T} \left[ \int_{-\infty}^{\infty} df \frac{\gamma^2(|f|)}{f^6 P_1(|f|) P_2(|f|)} \right]^{1/2}$$

In short-duration injections (~ an hour), the signal strength needs to be very large to guarantee signal detection.

*Theoretically predicted behavior of SNR for large strength injections:*





# Realizing long-duration injections: *Hurdles*

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## Software:

- 4 hours of data per detector occupy ~1 Gbytes
- Storage and transfer of day/week-long data impractical
- Solution: Produce simulated data on-site, on the fly

## Other Data Analysis:

The presence of a non-continuous stochastic signal could interfere with the detection of other signals



# The simulation / injection pipeline implementation

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1. A driver script calls the LAL executable (SimulateSB) at each site every  $X$  minutes to produce an  $X$  minute-long waveform and delete the last injected waveform
2. The stochastic signals at LHO & LLO are NOT independent: to preserve LHO-LLO covariance, GPS time used as seed at both sites

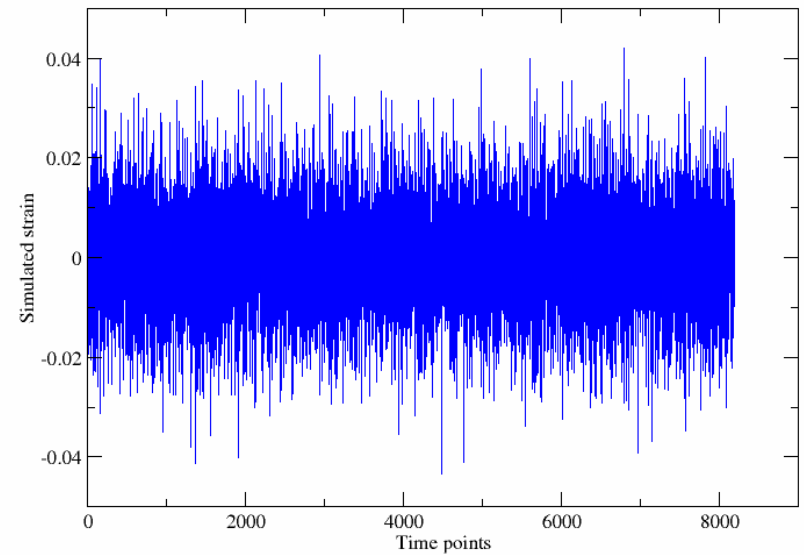
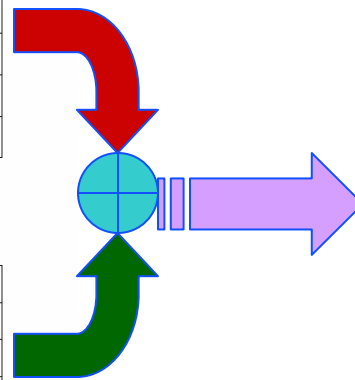
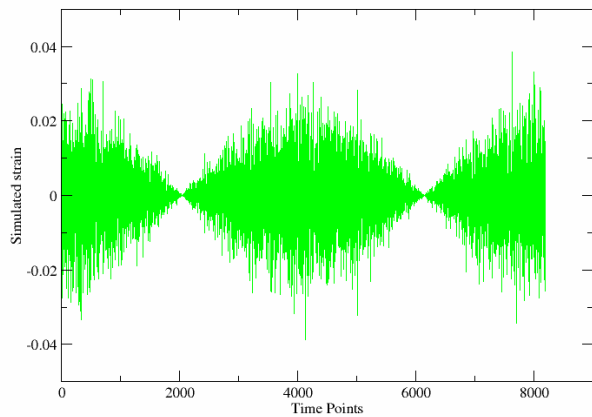
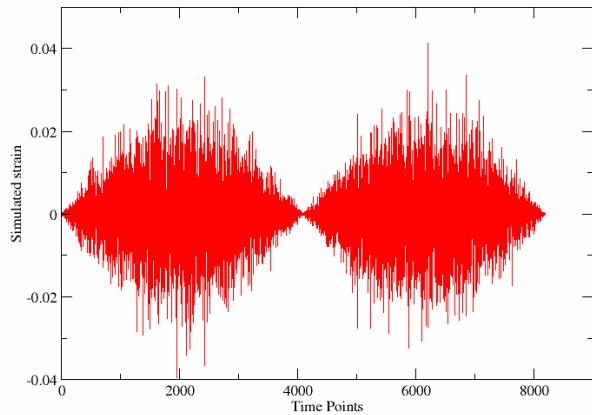
$$\langle \tilde{h}_A(f_i) \tilde{h}_B(f_j) \rangle = \left( \frac{3H_0^2 T}{20\pi^2} \right) f_i^{-3} \Omega_0 \gamma_{AB} \delta(f_i - f_j)$$

3. Time-series continuous from one function call to another...



# Continuous-in-time Injections

-- Allen, Romano, *GRASP*





## E10/S3 Hardware injections

- A > 10 hour long H1-H2 injection done @ end of E10
- Several long duration HW injections were accomplished on the wee-hours of Nov 7<sup>th</sup>, all with  $\Omega = 1$ :

Detector Pair	GPS start time	Injection Duration
H1-H2	752232759	3966
H1-H2	752242398	2824
H1-L1	752232937	3788
H1-L1	752242398	1315
H2-L1	752232937	10776



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