Prospects for Stochastic Background Searches Using Virgo and LSC Interferometers

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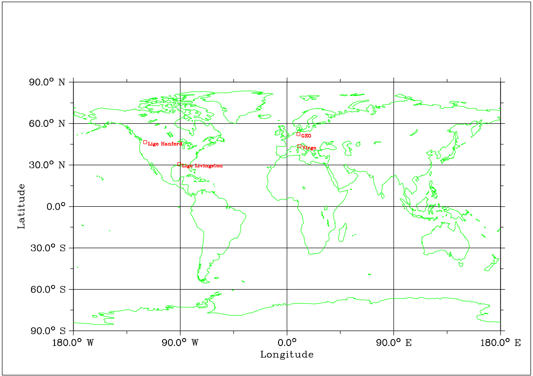
(for the LSC-Virgo working group on stochastic backgrounds)

11th Gravitational Wave Data Analysis Workshop

Outline

1. SBGW detection on a network
   - Isotropic background
   - Anisotropic background
2. Numerical results
   - Generalities
   - Detection



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Gaussian Case: Detection

- Signal probability distribution

$$dP = \mathcal{N} e^{-\frac{1}{2} C^{-1}_{AB}(f) s^*_A(f) s_B(f)} \prod_{C,f} ds_C(f)$$

- Detection problem: discriminate between

$$C^{(0)} = \begin{pmatrix} N_{11} & 0 \\ 0 & N_{22} \end{pmatrix} \quad \text{and} \quad C^{(1)} = \begin{pmatrix} N_{11} + S_{gw} & \gamma_{12} S_{gw} \\ \gamma_{12} S_{gw} & N_{22} + S_{gw} \end{pmatrix}$$

Solution: optimal correlator

$$Y_{12} \propto \int s_1^*(f) \frac{\gamma_{12}(f) S_{gw}(f)}{f^3 N_{11}(f) N_{22}(f)} s_2(f)\, df$$

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$$SNR^2 = 2F^2 T \int_0^\infty \gamma_{12}^2(f) \frac{S_{gw}^2(f)}{N_{11}(f) N_{22}(f)} df$$

γ express the coherence between the signals coupled to each detector

- SNR scales with γ
- γ Depends on detectors' distance and orientation
- γ's Frequency scale: $f_{AB}^* = \frac{c}{\ell_{AB}}$

Best overlap with Virgo:

Livingston & Hanford below 260 Hz
GEO above 260 Hz

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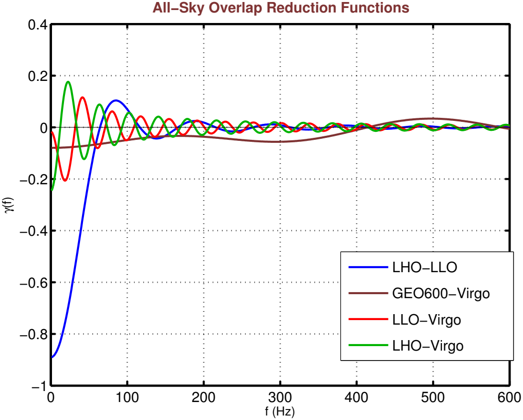

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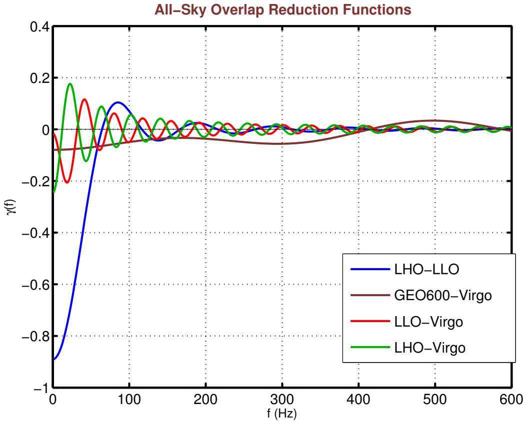
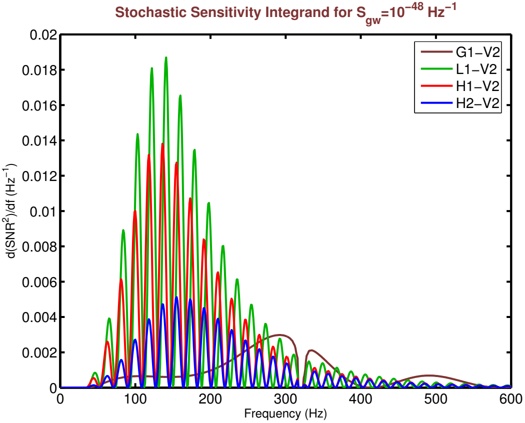


Sensitivity Integrand

$$\frac{d\,SNR_{AB}^2}{df} = 2F^2 T \gamma_{AB}^2(f) \frac{S_{gw}^2(f)}{N_{AA}(f) N_{BB}(f)} df$$



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- design sensitivity
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- $200 - 300\,Hz$: comparable sensitivities
- High frequency: GEO/Virgo pair can do better (smaller separation)

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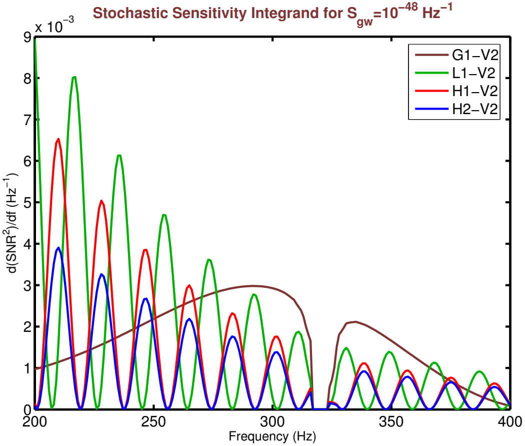

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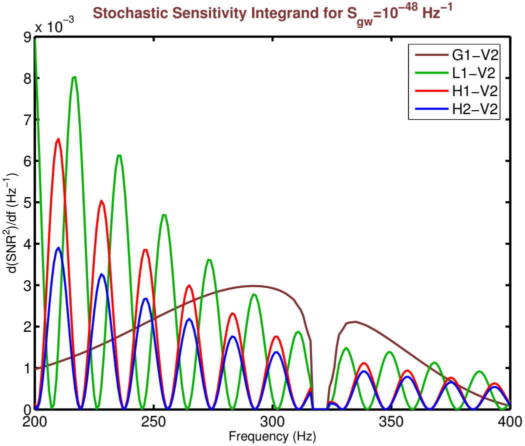

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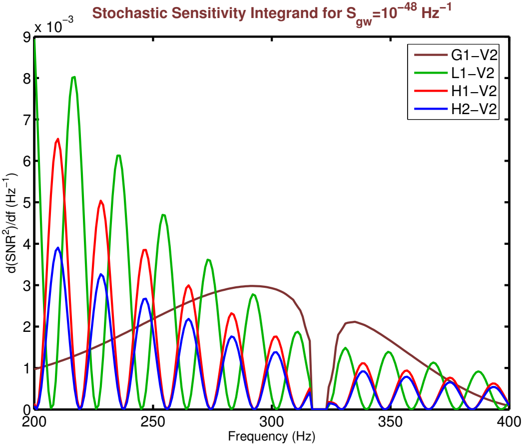

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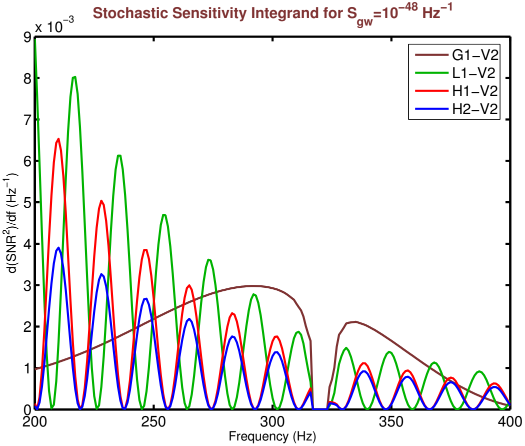

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Combined sensitivity

- SNR^2 are additive:
- We can define a combined sensitivity integrand

$$\frac{d\,SNR^2}{df} = \sum_{A>B} SNR^2_{AB}$$

- Overall improvement of a factor 2-3 with combined analysis
- Virgo contributes better when spectrum grows with frequency

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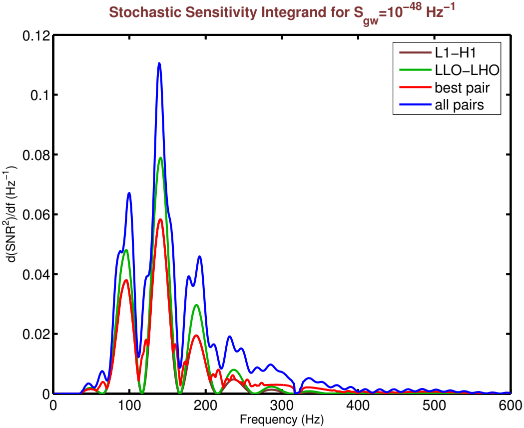

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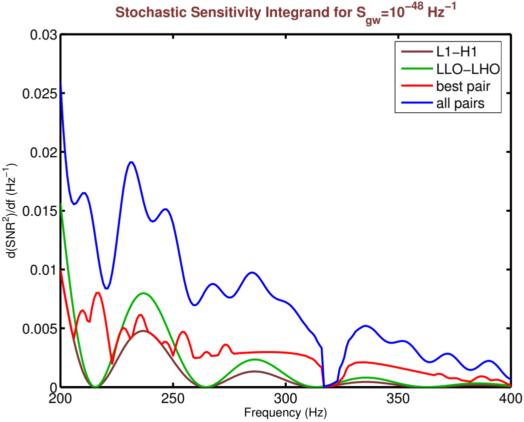

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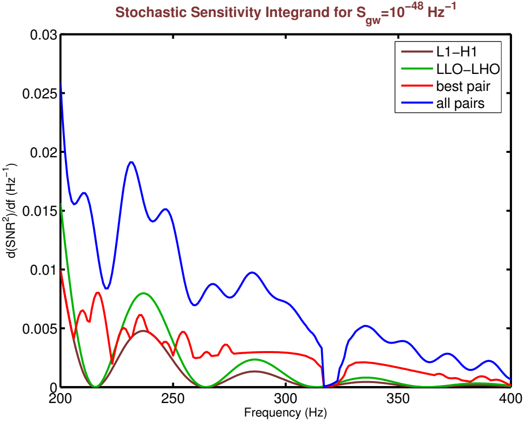

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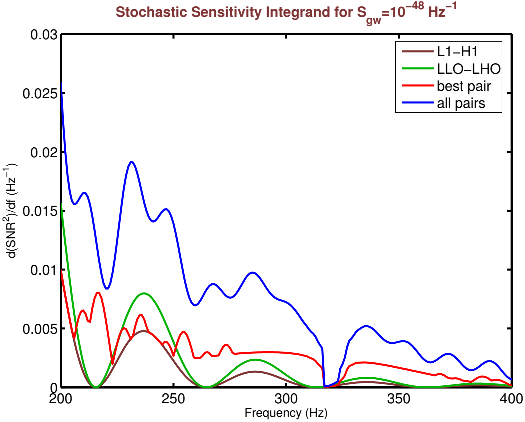
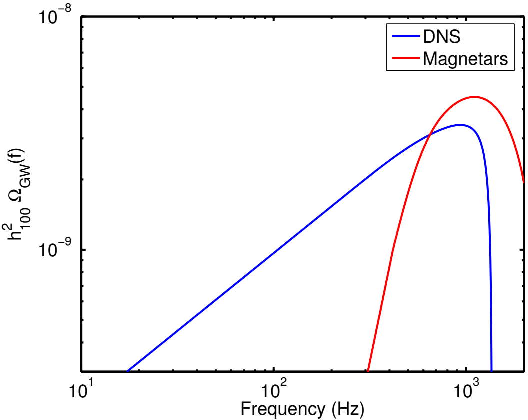


Astrophysical Models
(see T. Regimbau talk)



- Magnetars:

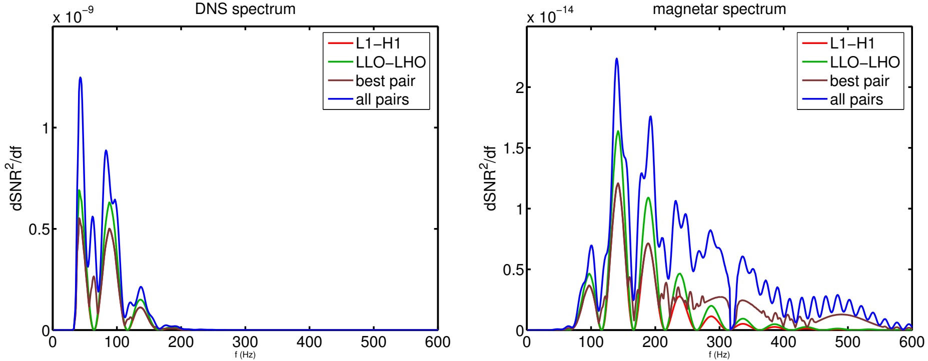
$$\Omega_{GW} \sim f^4$$

- Double Neutron Stars:

$$\Omega_{GW} \sim f^{2/3}$$

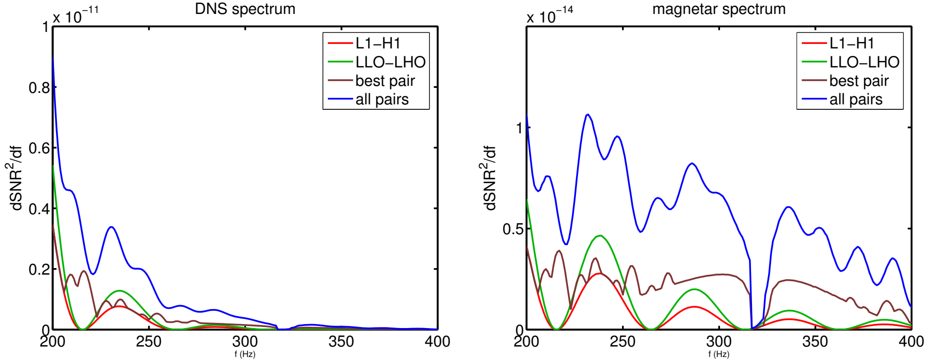
- Amplitudes well below the current sensitivities

Sensitivity integrands



Improvement of a factor 2-3 with the “full” network

Sensitivity integrands



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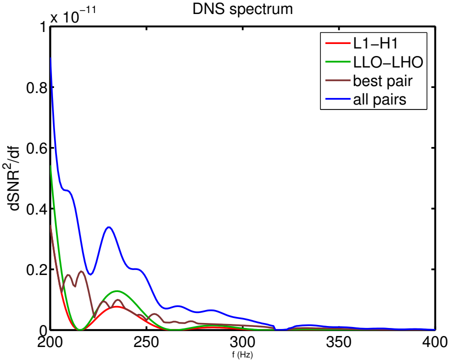
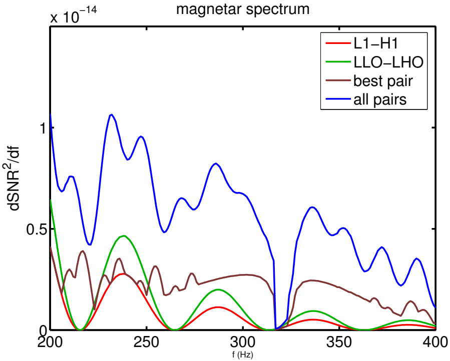
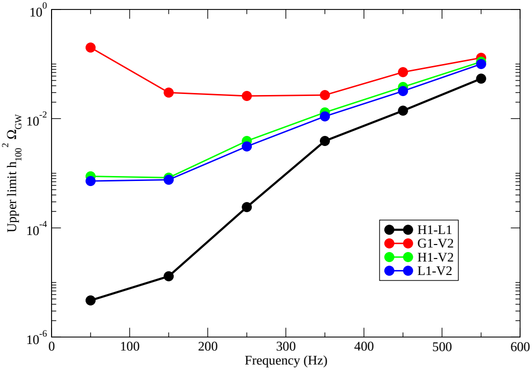




Improvement of a factor 2-3 with the “full” network

Upper limits



- Flat Ω_{GW}
- Current sensitivity (S5,WSR1)
- Design sensitivity

Improvement in the “high frequency” region

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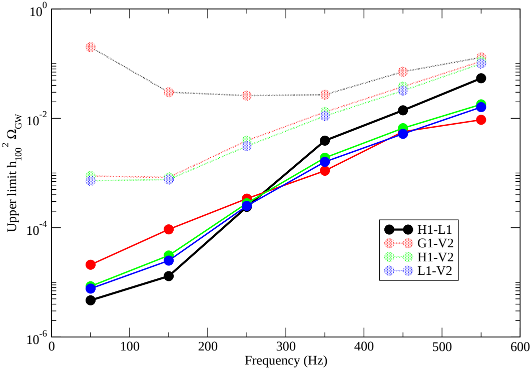

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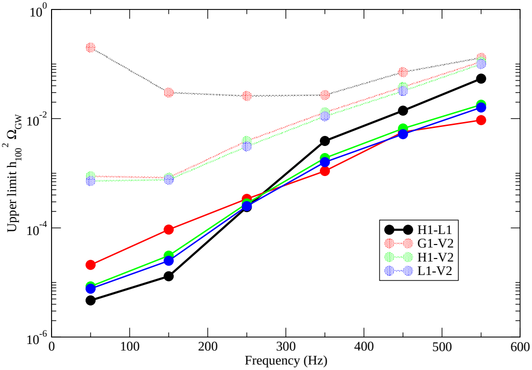

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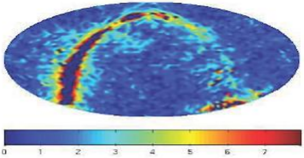
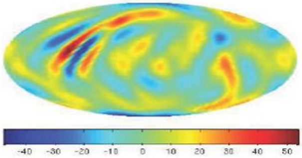
Anisotropic background

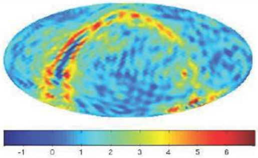
- Search for SGWB with delta function distribution
  - for grid of points on sky => 'sky map'
- Map is convolution of true distribution and response function
- Sanjit Mitra working on deconvolution
  - Conjugate Gradient iterative method



source map



'dirty' map – before deconvolution



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Not much to say until now, mainly question marks

- Sensitivity?
- Blind reconstruction or template-driven one?

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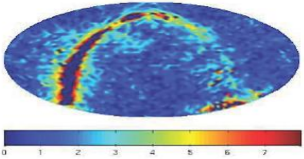

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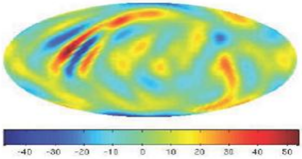

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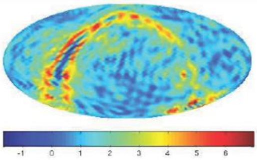

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  - Cholesky or SVD
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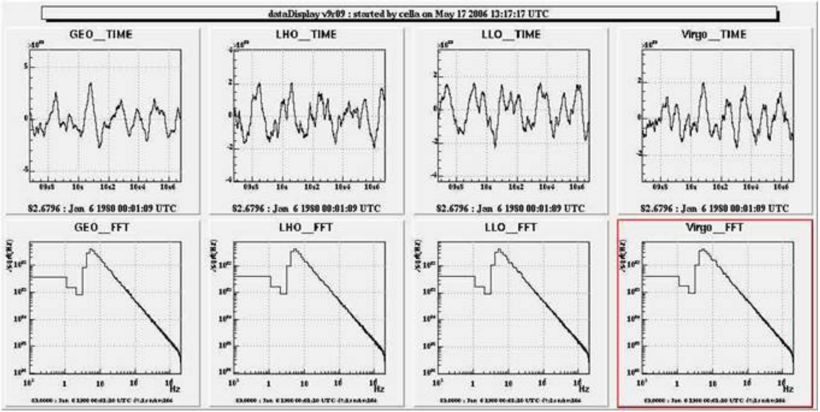
Checks: in the noiseless case

$$\frac{C_{AB}^{(1)}}{\sqrt{C_{AA}^{(1)} C_{BB}^{(1)}}} = \frac{S_{GW} \gamma_{AB}}{\sqrt{(S_{GW} + N_{AA})(S_{GW} + N_{BB})}} \to \gamma_{AB}$$

$$C_{AA}^{(1)} \to S_{GW}$$

Signal Generation Checks



- Time domain (flat Ω_{GW})

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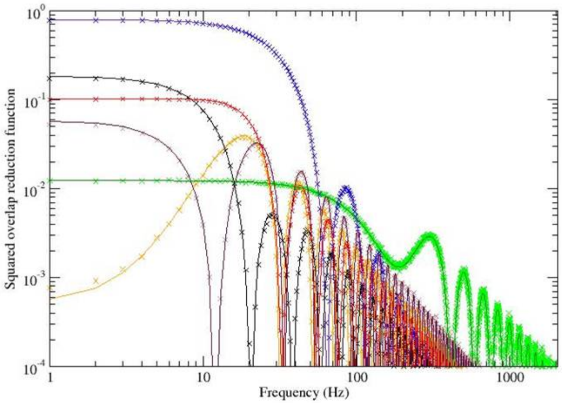

- Overlap reduction function recostruction (γ_{AB}^2)

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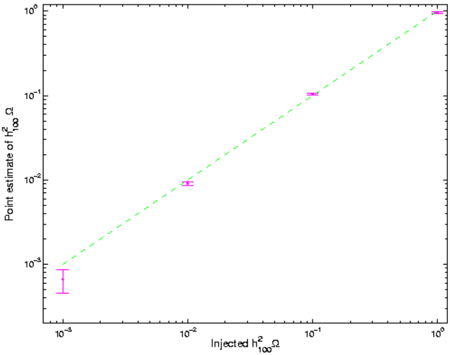

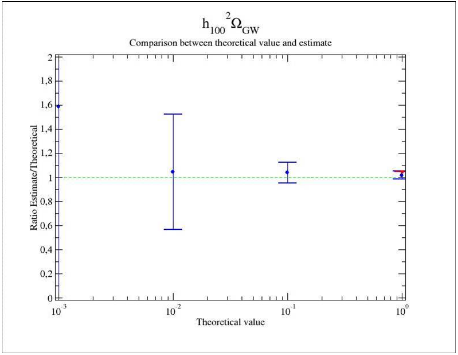

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- Results agree with expectations with all the used pipelines (both for simulation & detection)

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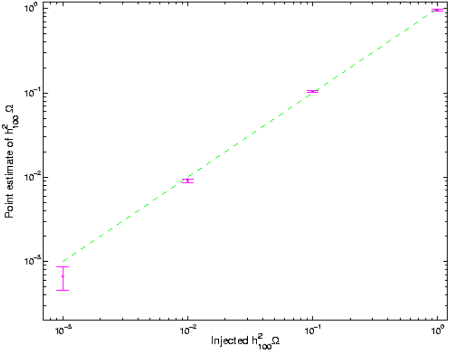

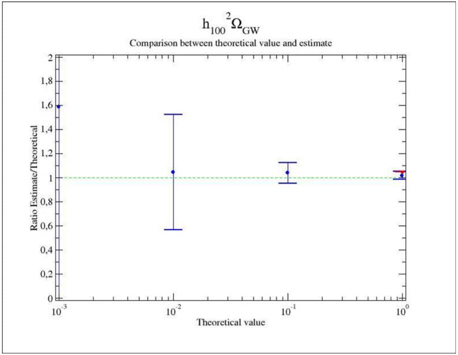

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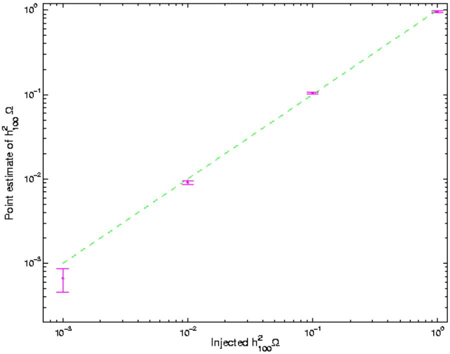

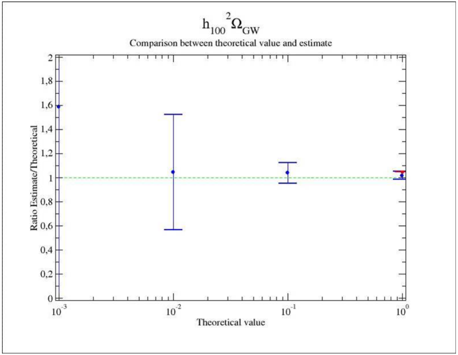

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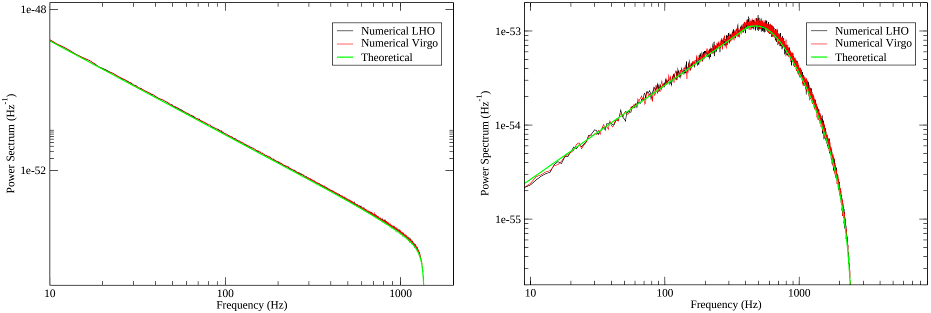

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- Magnetars & DNS spectrum scaled to different SNR ratios
- Analysis in progress

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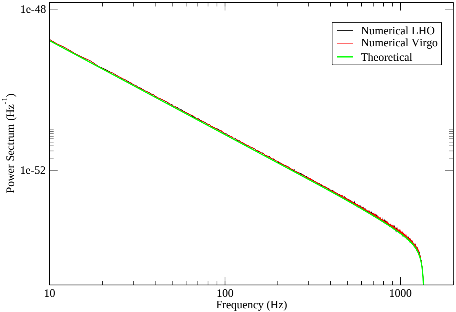

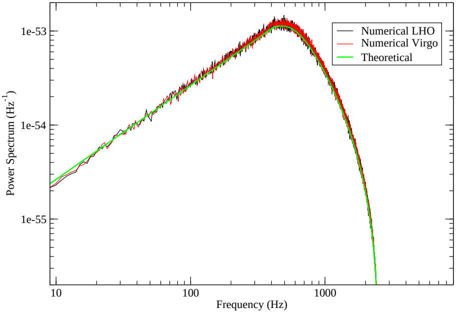

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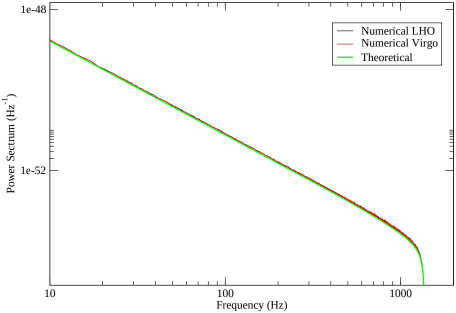

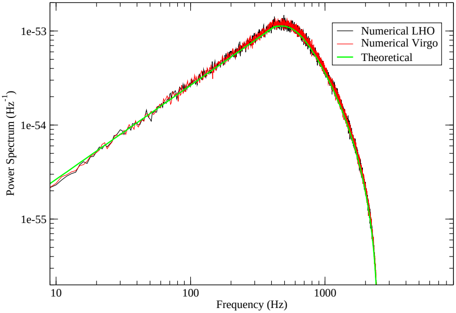

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Summary

- Virgo/LSC collaboration can improve the sensitivity and the robustness of stochastic background search.
- We are far from the perspective of a real detection, but we can improve upper limits and work in the perspective of second generation interferometers.

- Future steps:
  - Analysis of project1b data
  - Real data (as soon as MOU will be signed)
    - Non stationarity
    - Non gaussianity
  - Start with radiometer research