Characterizing Earth gravity field fluctuations with MIGA

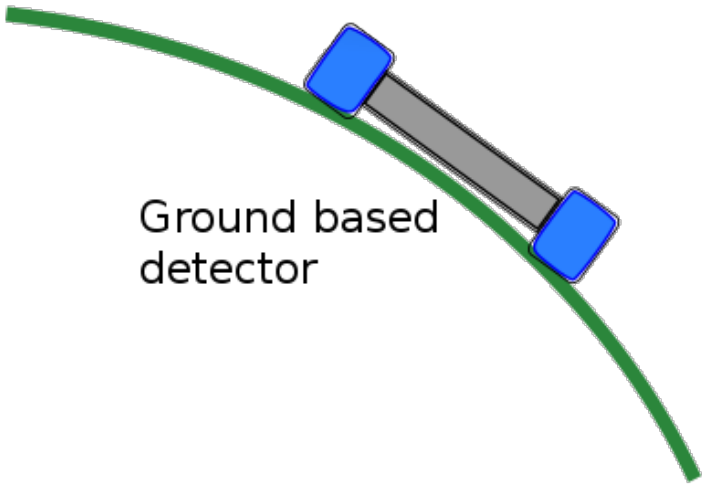
Joseph Junca

June 25, 2019

Introduction

- What is GGN ?
- Modelization of GGN
- GGN characterization with MIGA ?

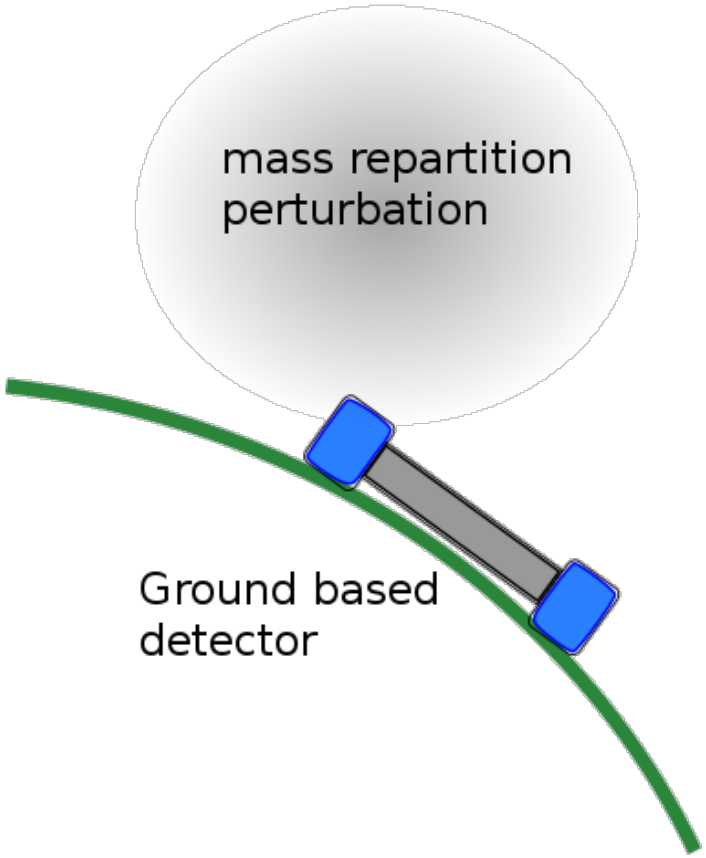
What is GGN ?



test masses

$\Downarrow$

What is GGN ?



test masses

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sensitivity to local acceleration variations

$\Downarrow$

GGN

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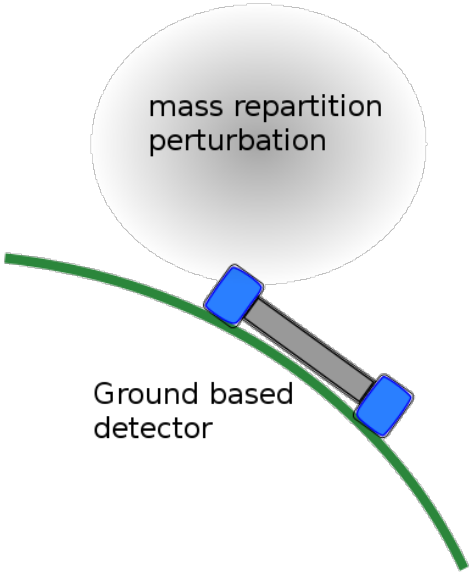

test masses
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sensitivity to local acceleration variations
$\Downarrow$
GGN

Possible sources:

$\rightarrow$ movement of the ground

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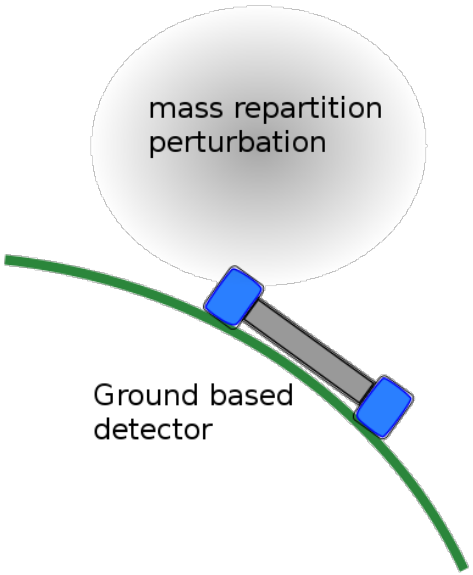

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sensitivity to local acceleration variations
$\Downarrow$
GGN

Possible sources:

- $\rightarrow$ movement of the ground
- $\rightarrow$ density variations within the atmosphere

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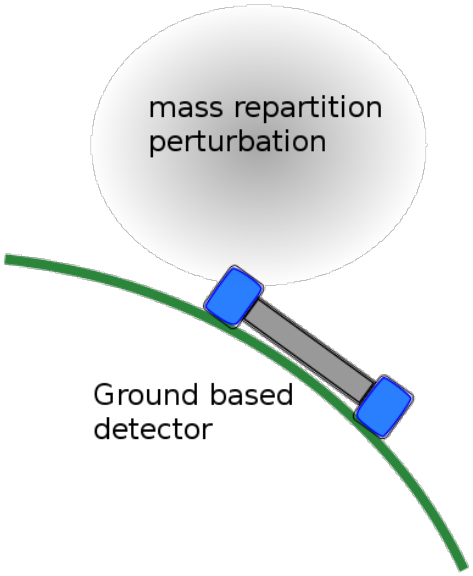

test masses
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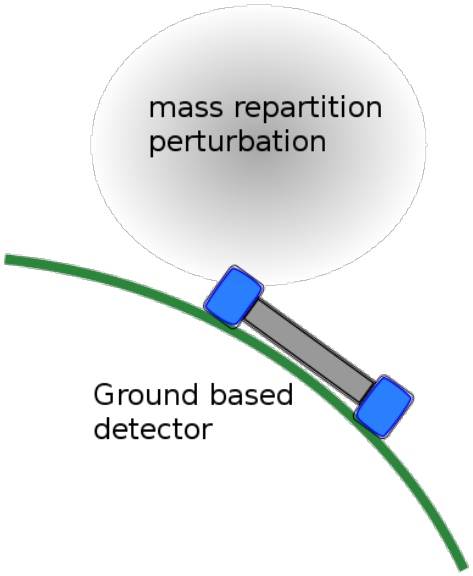
sensitivity to local acceleration variations
$\Downarrow$
GGN

Possible sources:

- $\rightarrow$ movement of the ground
- $\rightarrow$ density variations within the atmosphere
- $\rightarrow$ movement of a mass nearby the detector

What is GGN ?



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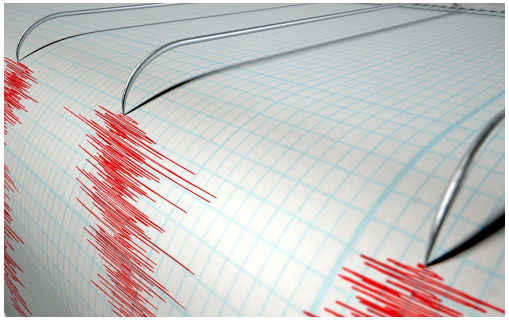
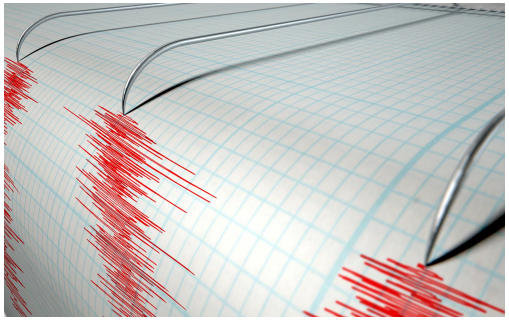
GGN modelization: seismic contribution



seismic activity

$\Downarrow$

GGN modelization: seismic contribution



seismic activity

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movement of the ground

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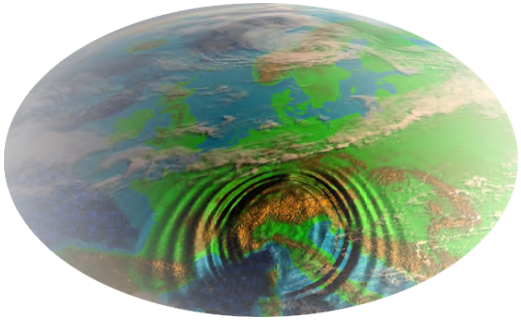
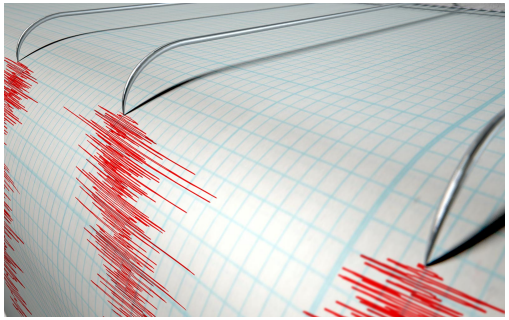


GGN modelization: seismic contribution



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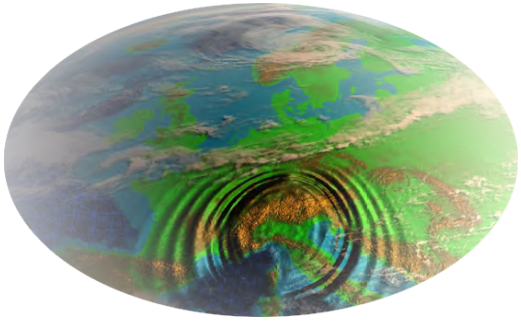
GGN



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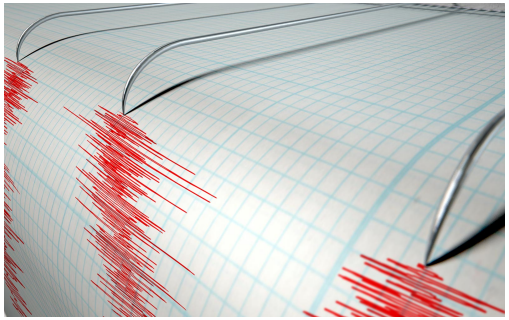

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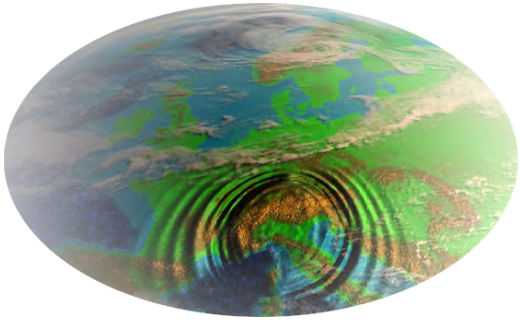
GGN

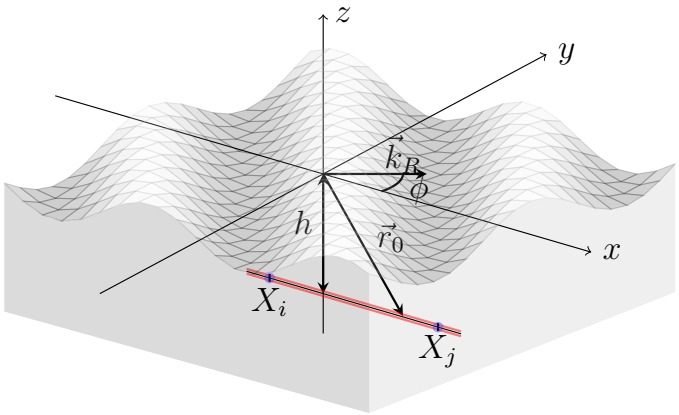


What amplitude is to be expected?

GGN modelization: seismic contribution

Hypothesis of the theoretical calculus:

- → Rayleigh waves
- → isotropic seismic activity
- → homogeneous medium



Results:

$$S_{\Delta a_x}(\omega, L) = H_R^2(\omega, L) S_{\ddot{\xi}_z}(\omega) \tag{1}$$

GGN modelization: seismic contribution

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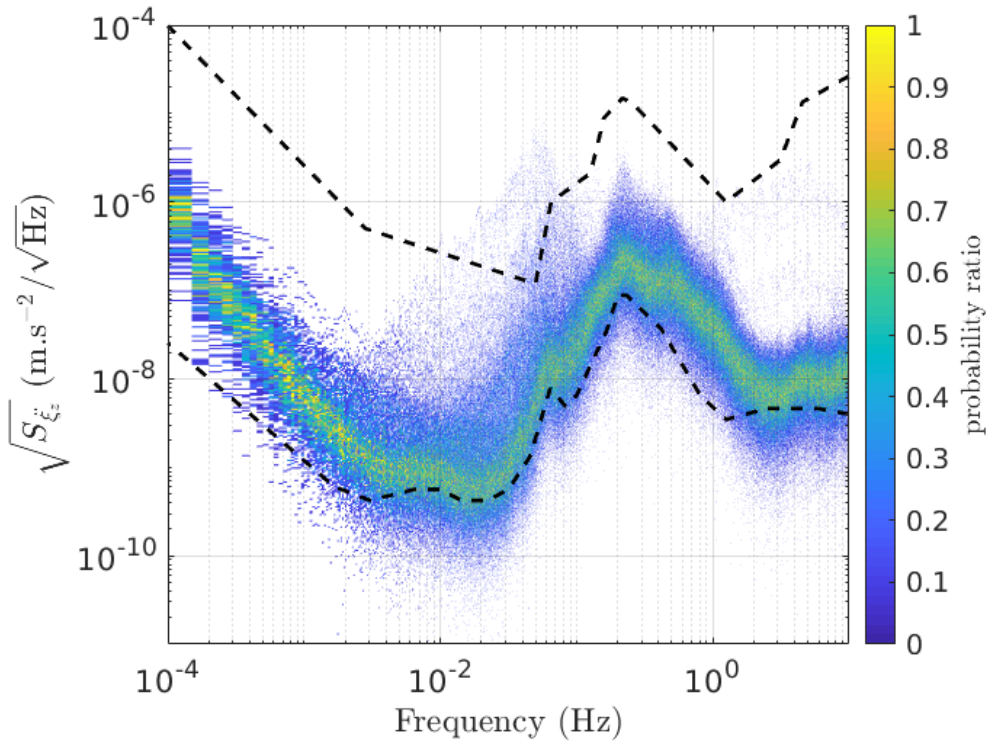

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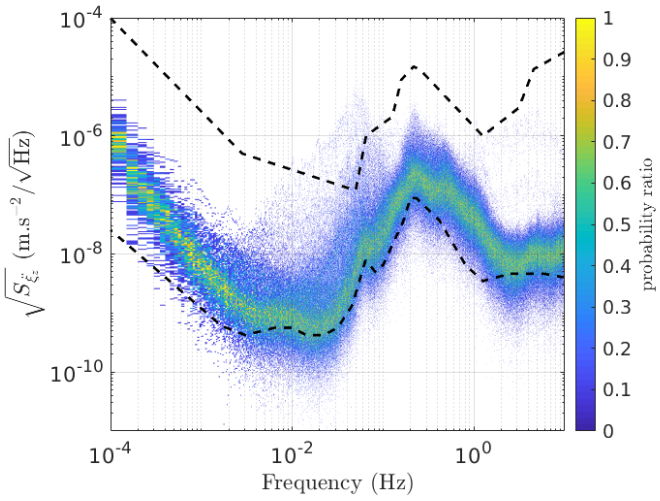

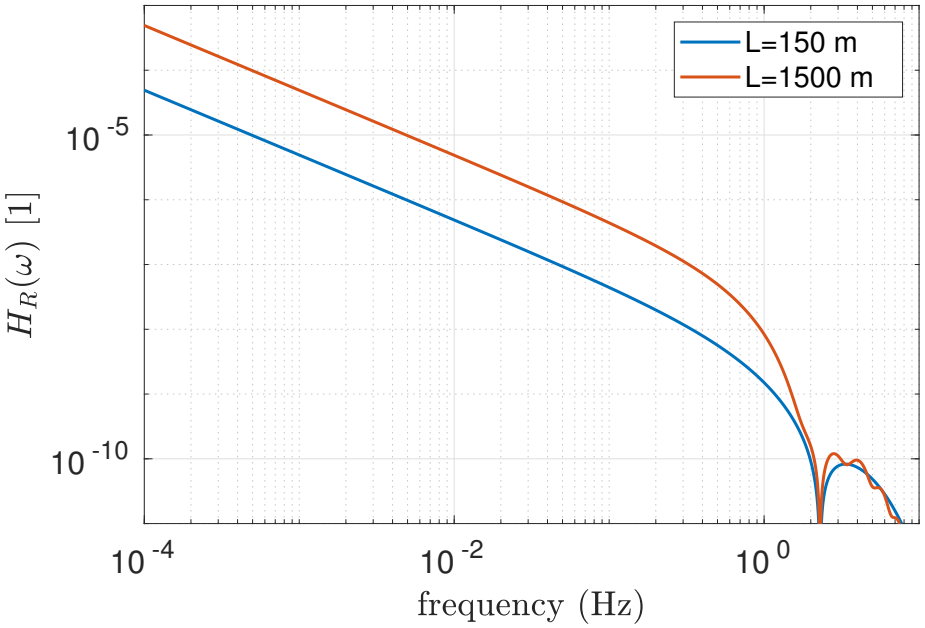

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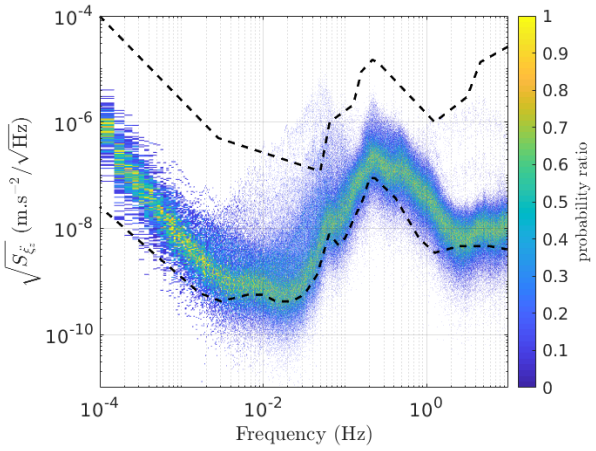

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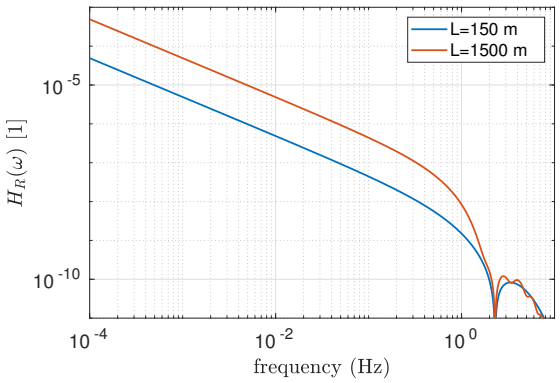

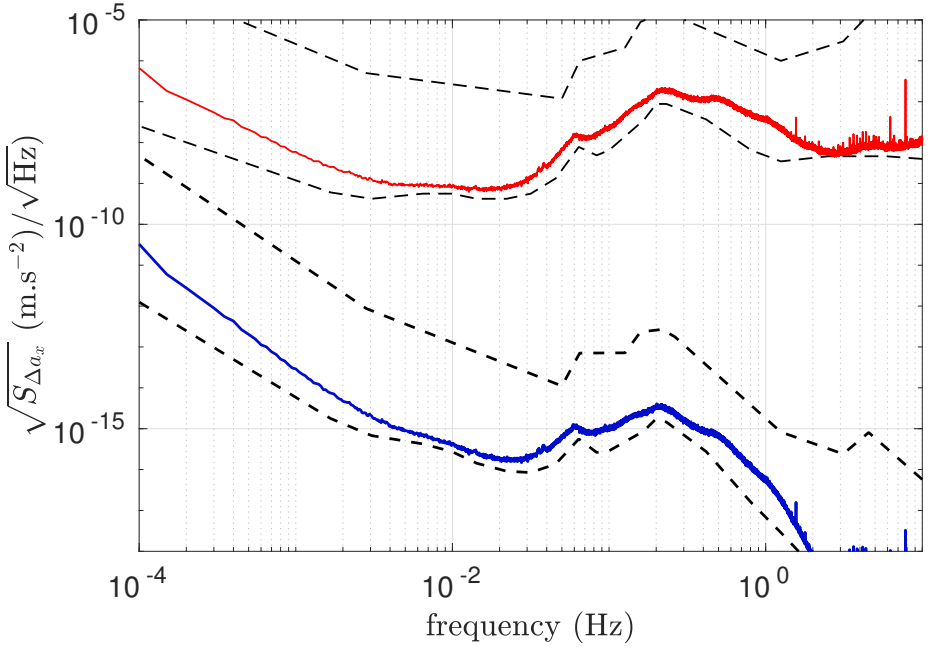

GGN modelization: infrasound contribution

soundwaves in the atmosphere

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GGN modelization: infrasound contribution

soundwaves in the atmosphere

$\Downarrow$

density variation within the atmosphere

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GGN modelization: infrasound contribution

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GGN

GGN modelization: infrasound contribution

soundwaves in the atmosphere

$\Downarrow$

density variation within the atmosphere

$\Downarrow$

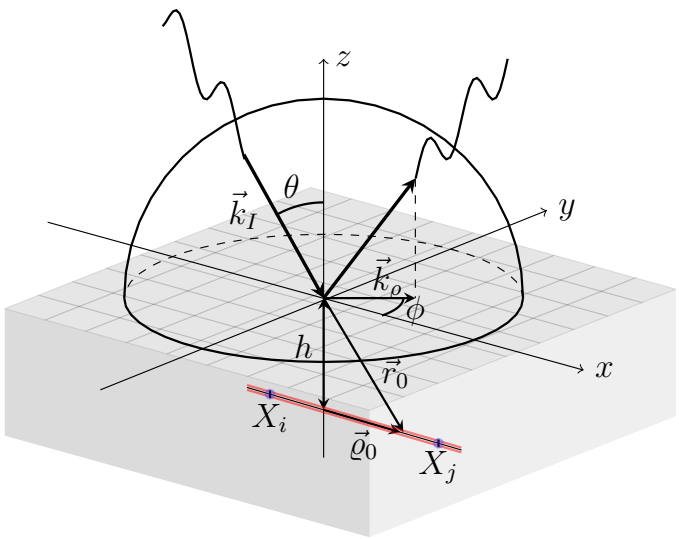
GGN

What amplitude is to be expected?

GGN modelization: infrasound contribution

Hypothesis of the theoretical calculus:

- → adiabatic compressional plane waves
- → isotropic direction of propagation
- → total reflection onto the surface of the ground
- → homogeneous atmosphere



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$$S_{\Delta a_x}(\omega, L) = H_I^2(\omega, L) S_{\delta P}(\omega) \tag{2}$$

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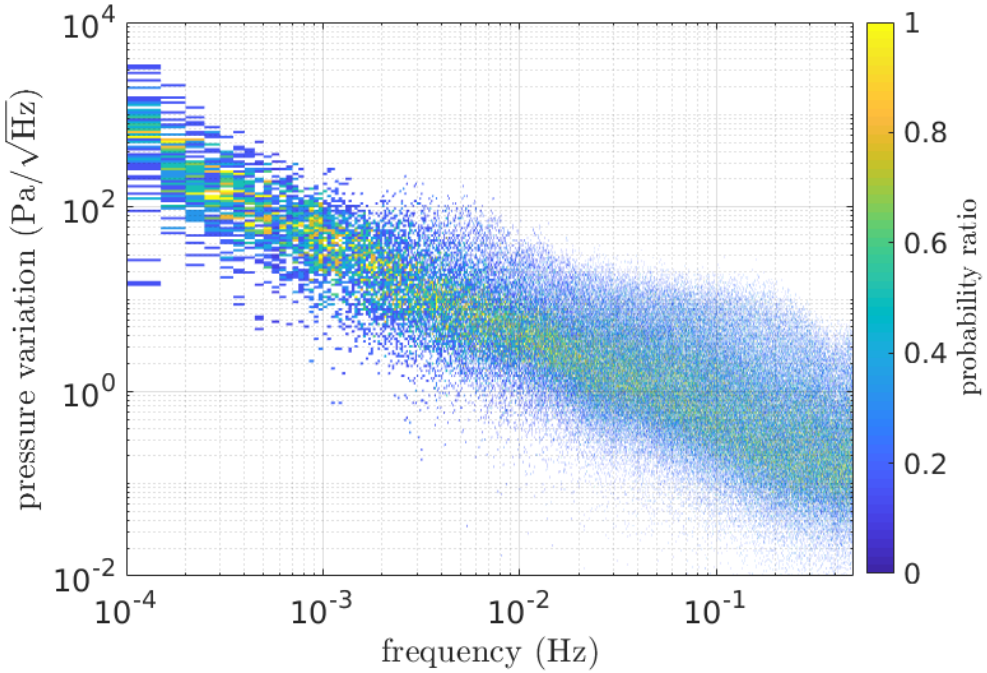

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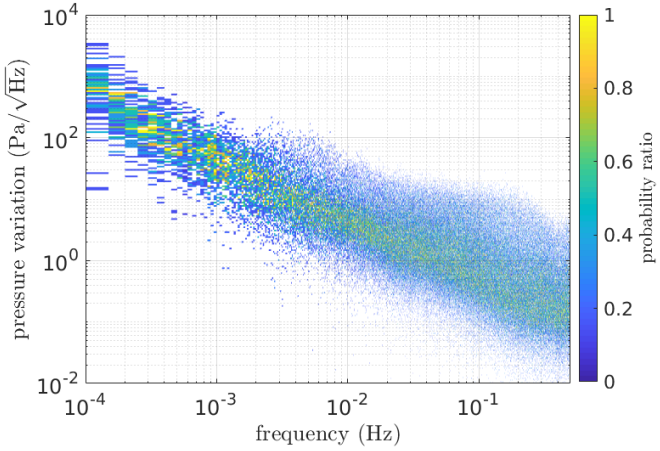

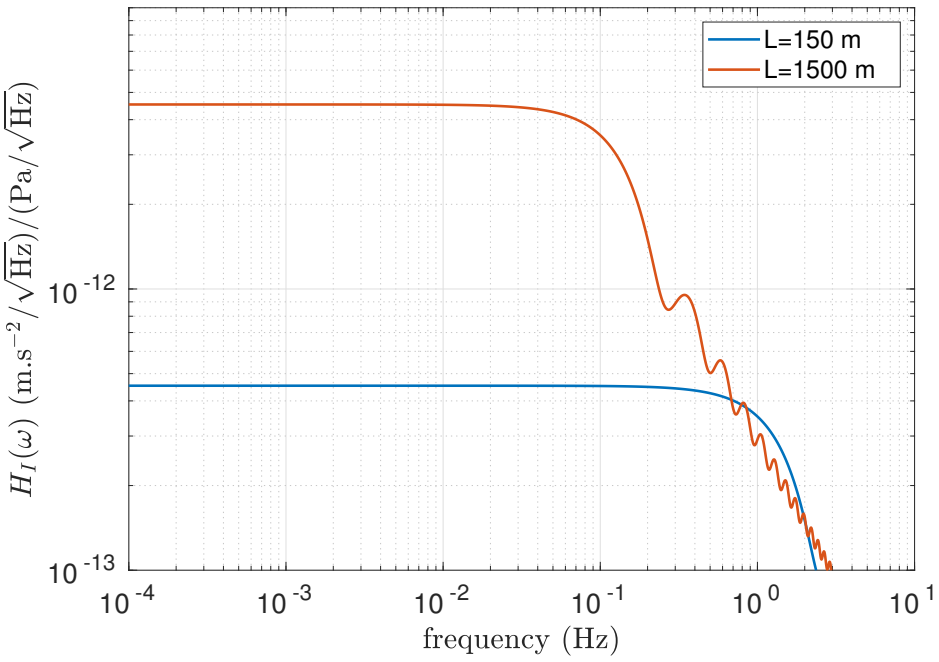

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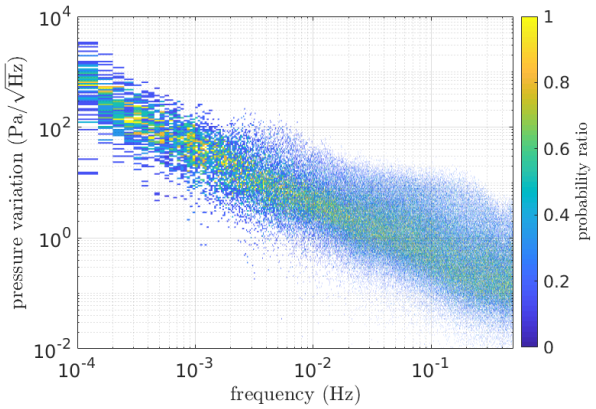
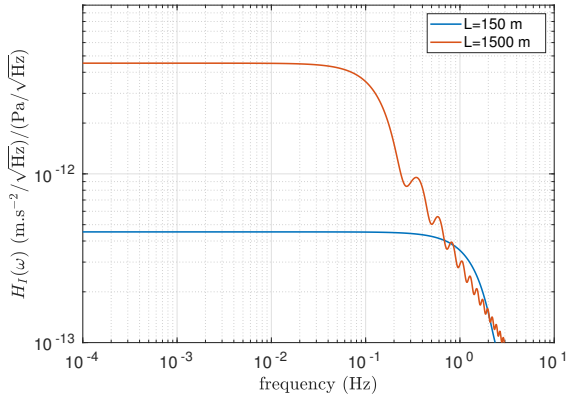
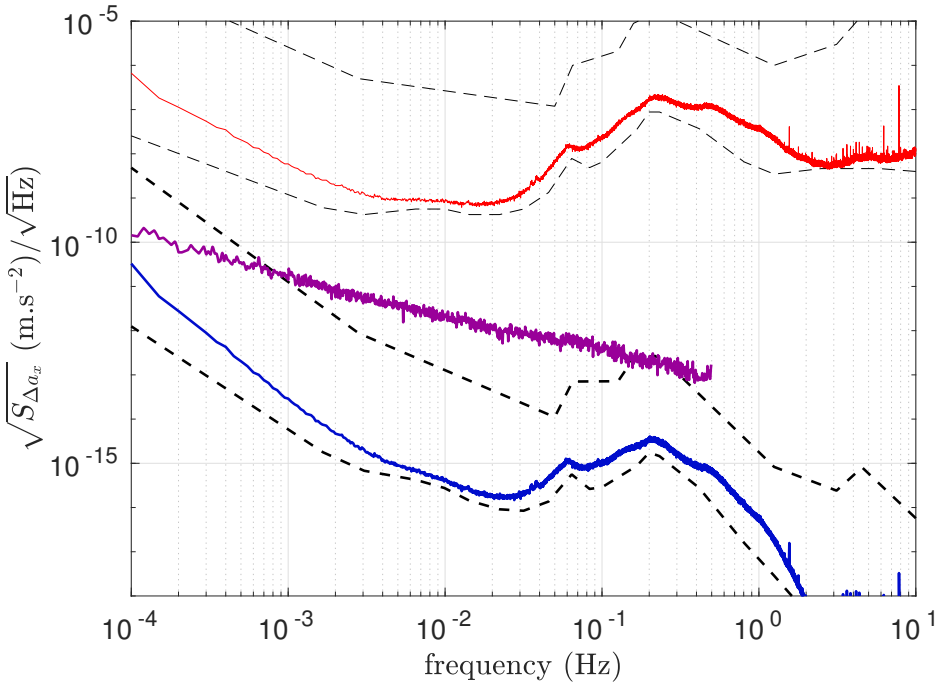
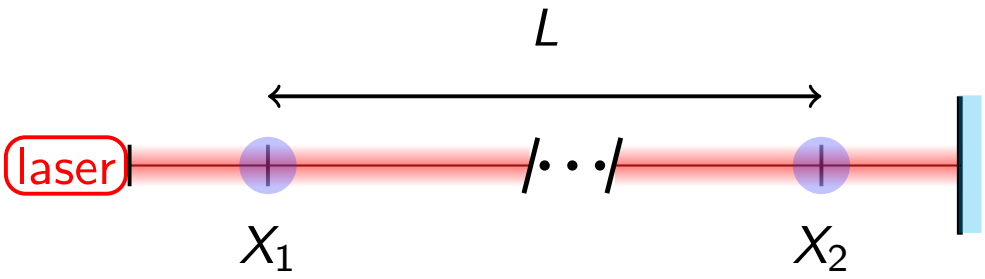




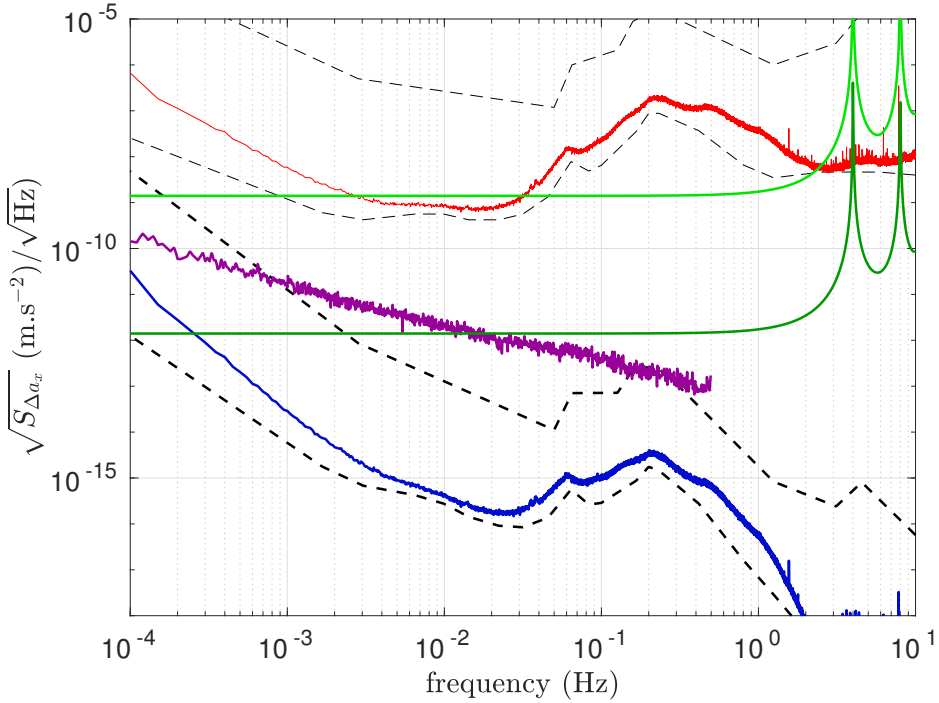


GGN characterization with MIGA ?



2 atom interferometers simultaneously interrogated along a common laser beam.

MIGA sensitivity to differential acceleration.



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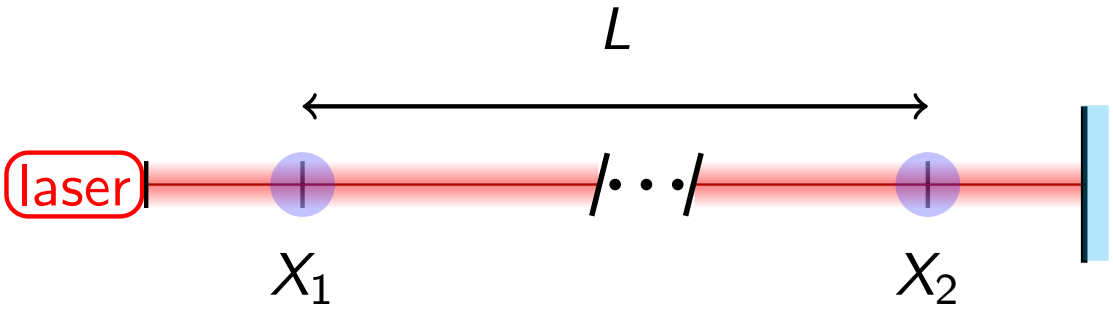
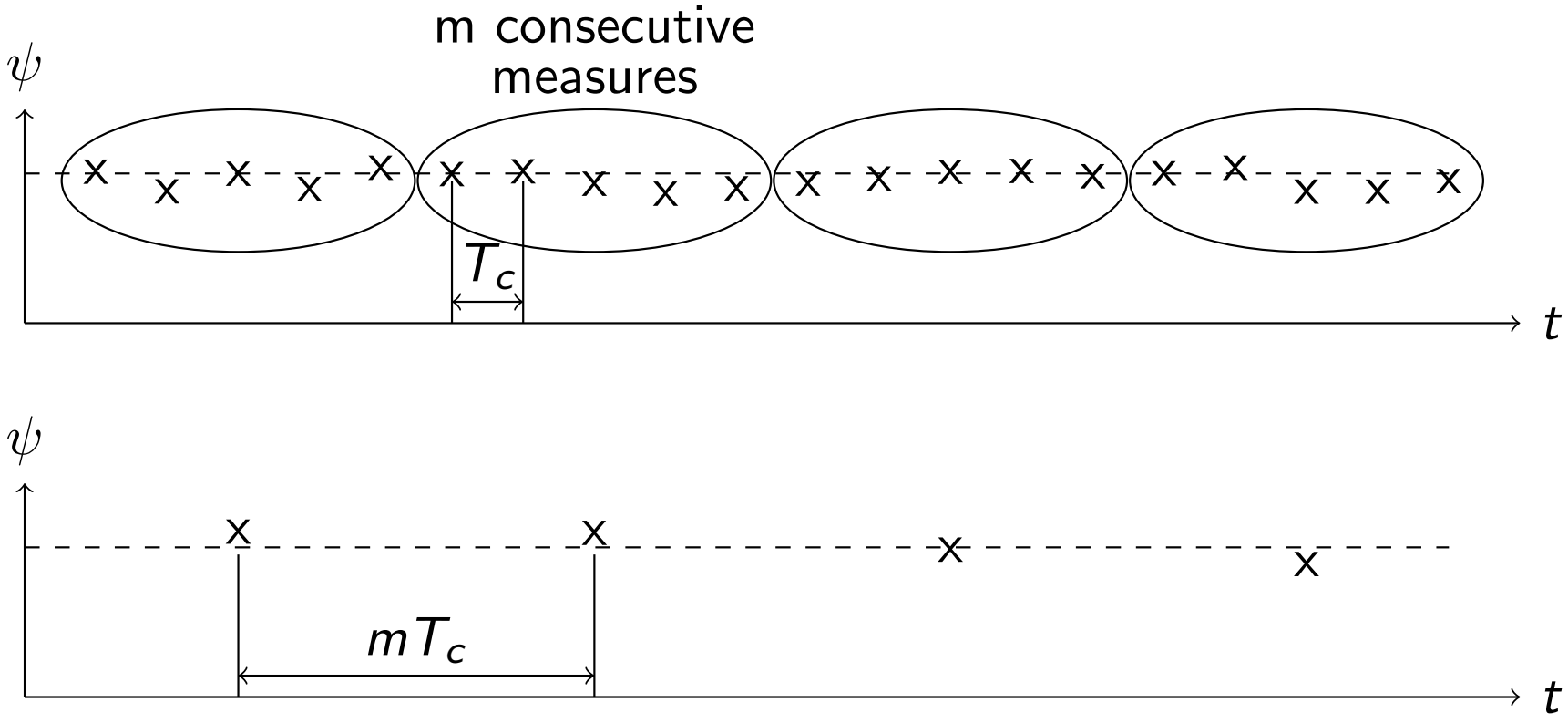


Differential interferometric phase:

$$\psi(X_1, X_2, t) = \int_{-\infty}^{+\infty} g'(\tau - t)(\Delta\varphi_{las}(X_1, \tau) - \Delta\varphi_{las}(X_2, \tau))d\tau \quad (3)$$

GGN characterization with MIGA ?

Indirect detection scheme based on the measure of the Allan variation



GGN characterization with MIGA ?

$$\sigma_\psi(mT_c) = \int_0^{+\infty} H_m^2(\omega) S_{\Delta a_x}(\omega) \frac{d\omega}{2\pi} \qquad H_m(\omega) = \frac{2\sqrt{2} n k_L}{m} \frac{\sin^2(m\omega T_c/2)}{|\sin(\omega T_c/2)|} \frac{4\sin^2(\omega T/2)}{\omega^2}$$

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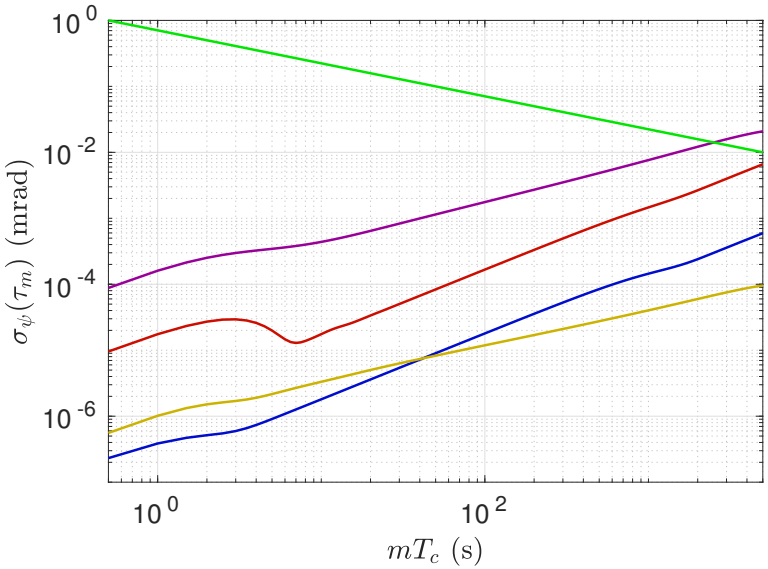
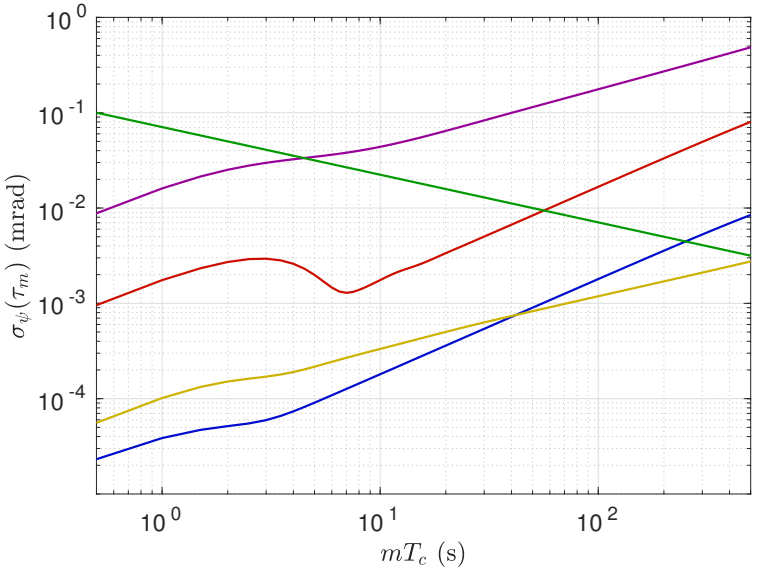


initial configuration



improved configuration

Conclusion

- GGN modelisation from seismic Rayleigh waves
- GGN modelisation from infrasound within the atmosphere
- comparison with MIGA target sensitivities
- scheme for indirect detection of GGN signal with MIGA

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Characterizing Earth gravity field fluctuations with the MIGA antenna for future gravitational wave detectors

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[3]*LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, 61, avenue de l'Observatoire, F-75014 Paris, France*