# Characterization of the stochastic signal originating from compact binary populations as measured by LISA

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# Gravitational waves

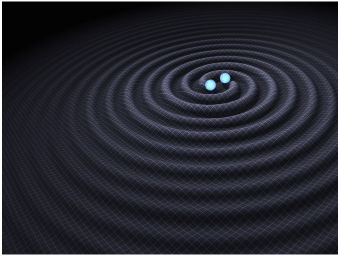
Ripples in space-time caused by accelerated masses.

## Einstein field equations

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu} \qquad |h| << 1$$

$$\bar{h}_{\mu\nu} = h_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu} h$$



Credit: R. Hurt (Caltech-IPAC)

# Gravitational waves

Lorenz gauge: $\partial_\mu \bar{h}^{\nu\mu} = 0$

**Wave equation**

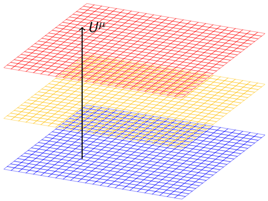
$$\Box \bar{h}_{\mu\nu} = 0$$

$$\bar{h}_{\mu\nu} = A_{\mu\nu} \exp\left(ik_\alpha x^\alpha\right)$$

Transverse traceless gauge:
$\bar{h}_{\mu\nu} U^\mu = 0$ and $\bar{h}_\mu{}^\mu = 0$

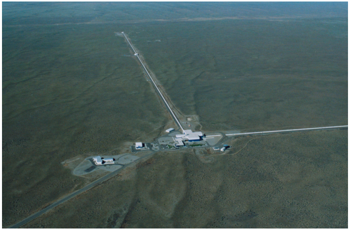
$$16 \xrightarrow{symetry} 10 \xrightarrow[gauge]{Lorenz} 6 \xrightarrow[gauge]{TT} 2$$

$$h_{\mu\nu} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & h_+ & h_\times & 0 \\ 0 & h_\times & -h_+ & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

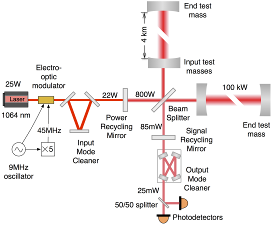


# LIGO Structure

## Giant Michelson interferometer



Credit: Caltech/MIT/LIGO Lab

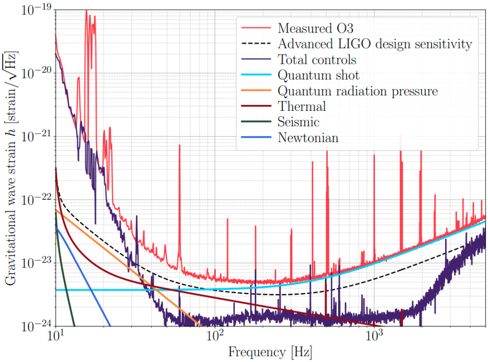



Credit: D. V. Martynov et all, 2018

$$S(t) = h(t) + n(t)$$

# LIGO Noise budget

Hanford detector



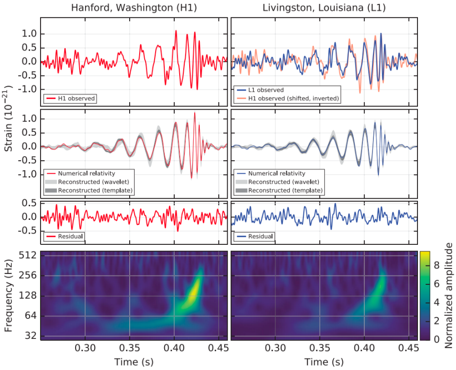

Credit: Craig Cahillane et all, 2022

Dominant noise:

- Quantum shot in high frequency
- seismic noise in low frequency

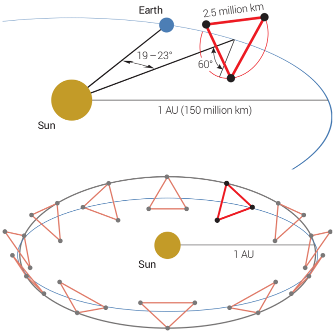
# First detection

GW150914

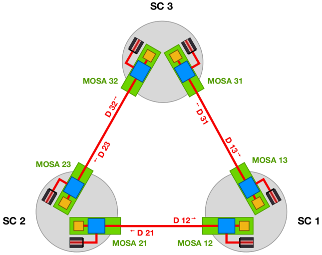



Credit: B. P. Abbott et al., 2016

# Laiser Interferometer Space Antenna

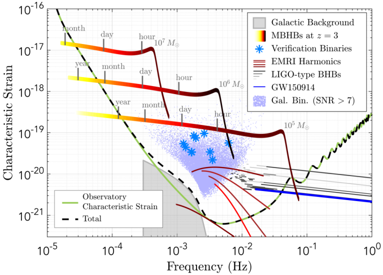



Credit: Karsten Danzmann et al., 2017




Credit: Jean-Baptiste Bayle et al., 2021

# LISA Band




Credit: Karsten Danzmann et al., 2017

GW sources in LISA band

- Supermassive black hole binaries (SMBHBs)
- Stellar-mass black hole binaries (SBBHs)
- Ultracompact galactic binaries (CGBs)
- extreme mass ratio inspiral (EMRIs)
- stochastic GW background

# LISA Isuues

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- LISA sources are expected to be long-lived
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- Some signals can be resolvable due to high signal to noise ratio
- remaining signals will affect the sensitivity as extra noise (confusion noise)

# Overview

- Simulating around 30 milion CGBs from Radler LISA data challenge dataset
- Simulating the instumental noise using the LISA code simulatior
- For each $T_{obs}$ gererate the idealized dataset in the frequency domain
- Apply the method to find the final sensitivity
- Fit the data with theoretical curve

# Methode

- Assumpion: Bright sources with a signal-to-noise ratio larger than a given threshold are detected and characterized without systematic bias or source cofusion.

## SNR

$$\rho^2_{tot} = \sum_k (h_k|h_k), \quad \text{k:noise-orthogonal TDI variables}$$

$$h_k|h_k = 4\int_0^\infty df \frac{|\tilde{h}_k(f)|^2}{\tilde{S}_n(f)}, \quad \tilde{S}_n(f) : \text{one-sided PSD}$$

$$\tilde{S}_n(f) = \tilde{S}_{instr}(f) + \tilde{S}_{conf}(f)$$

# Methode

1. Simulating 30 milions CGBs
2. Calculating the PSD of the signal and the instrumental noise
3. Calculating the SNR of each source with respect to the instrumental noise ($\rho_i^{iso}$)
4. Stimating the SNR of each source using either a running mean or median on the power spectrum of the data ($\rho_i$)
5. If $\rho_i > \rho_0$ the source will be subtracted from the data
6. iterate the process

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# GW151226

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# Our Group

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# Reference

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Thank you!