BDGWM 2023

Parallel Sessions Overview

Astrophysics and Cosmology

Parallel Session 1

Universiteit Leiden

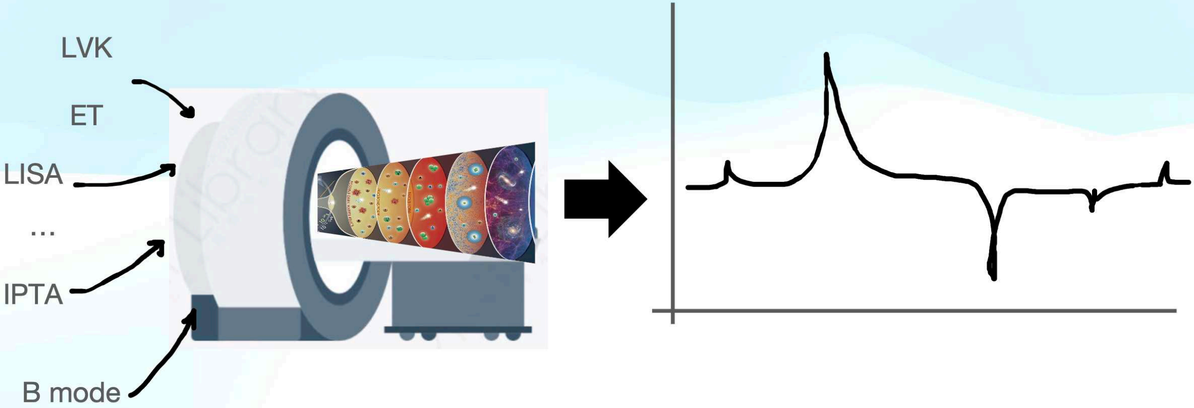
Instituut-Lorentz

Spacetime Oscillation and the Gravitational Wave Background

arXiv:2307.05455,
Gen Ye and Alessandra Silvestri

Gravitational Spectropy

of the Early Universe



Belgian-dutch GW meeting

First order phase transitions in the early universe and quantizing particles across the wall

Miguel Vanvlasselaer
miguel.vanvlasselaer@vub.be

VUB and IIHE brussels

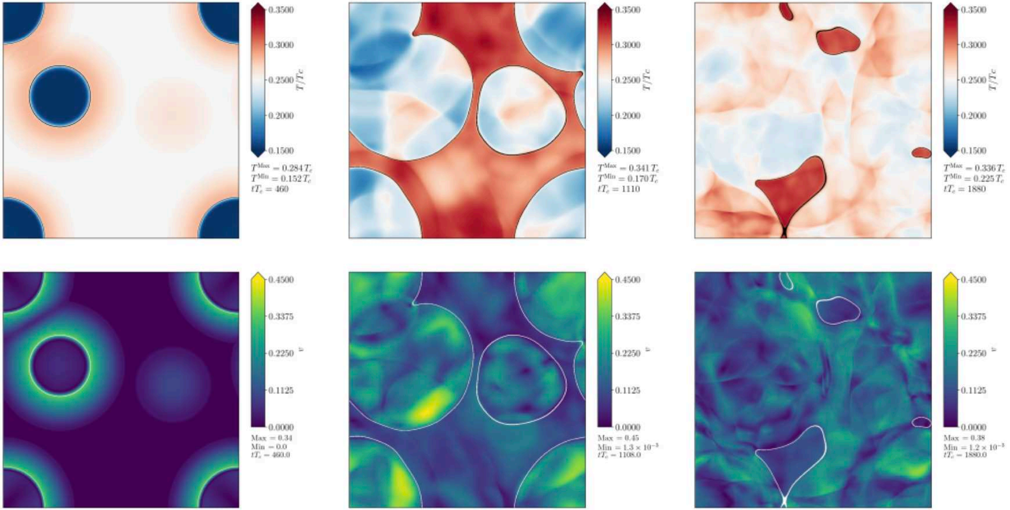
November 2023

VRIJE UNIVERSITEIT BRUSSEL

FOPT pictorially

Cutting, Hindmarsh and Weir:[1906.00480]: video in

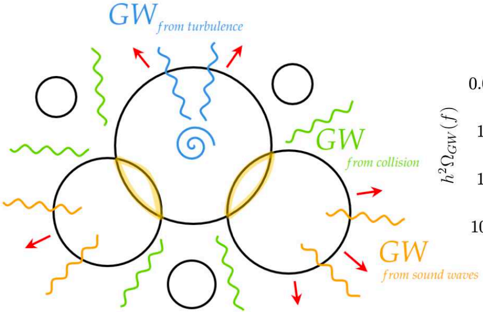
https://vimeo.com/showcase/5968055

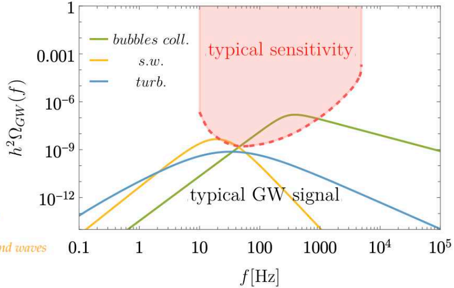


FOPT: What is the interest? GW

1. Bubbles can produce a stochastic GW background from

- bubble collision
- sound waves
- turbulence





Primordial GWs could be observed soon: Frequency $\Rightarrow$ information about T_{reh}: $f_{\text{peak}} \propto T_{\text{reh}}$

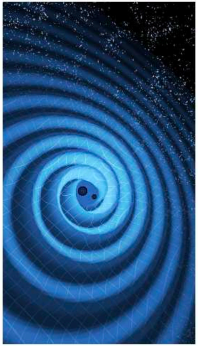
Take-home message

- FOPT are related to baryogenesis, Dark matter, primordial black holes and observable GW
- Their efficiency depends on v_w.
- In the relativistic regime, three contributions: i) $1 \to 1$: γ^0, ii) $1 \to$ heavy: γ^0, ii) τ :$1 \to 2$: $\gamma^1 \log v/T$
- Procedure for computing $1 \to 2$: i) define complete basis (LM and RM), ii) define global dof $\lambda \to \phi_2$, iii) split properly the phase space integral
- Conclusion: λ :$1 \to 2$: γ^1. Can dominate for $v/T \sim 1$.

Ringdown of rotating black holes in higher-derivative gravity

Simon Maenaut

Pablo Cano, Thomas Hertog,
Kwinten Fransen, Tjonnie Li,
Gregorio Carullo and Ania Liu
[2304.02663 and 2307.07431]



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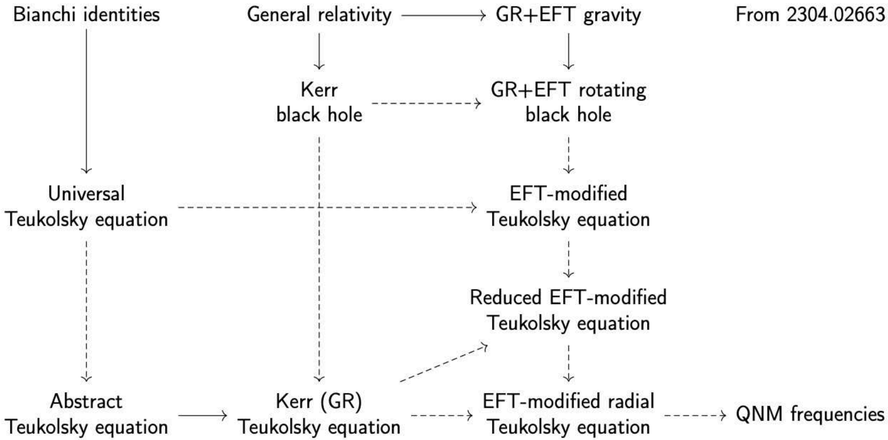
BE-NL GW-Meeting 2023

Universal Teukolsky equation near Kerr



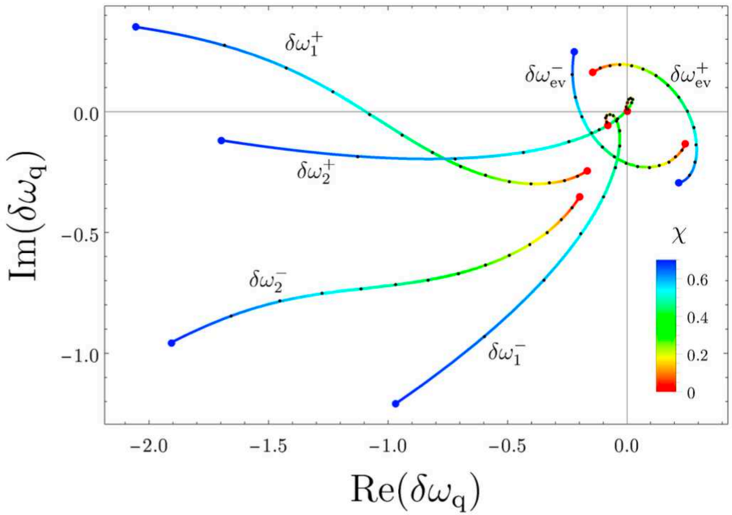


Figure: Shift in the 220 QNM frequency relative to Kerr [arXiv:2307.07431]

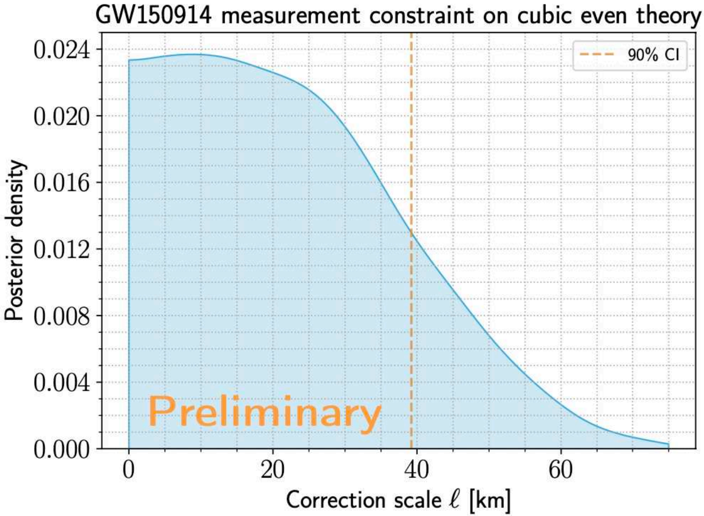


Figure: Calculated constraints on ℓ from the ringdown analysis of GW150914

Conclusions

- QNMs of rotating BHs with the universal Teukolsky equation
- Applied to the general EFT class of higher derivative gravity
- Correction coefficients were calculated up to ~ 0.7 in spin
- Preliminary analysis shows constraints from current data
- Sensitivity of future GW detectors from further analysis

Tidal properties of neutron stars in scalar-tensor theories

Gastón Creci
Institute for Theoretical Physics, Utrecht University
In collaboration with Tanja Hinderer and Jan Steinhoff
Based on arXiV:2308.11323

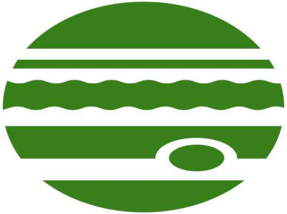
24/10/2023 - Belgian-Dutch Gravitational Wave Meeting, Maastricht

Case study: Neutron stars in scalar-tensor theories

Full theory: perturbative calculation

- Split the fields into background and perturbation

$$g_{\mu\nu} = g^{0}_{\mu\nu} + \epsilon \; h_{\mu\nu} \qquad \varphi = \varphi_0 + \epsilon \; \delta\varphi$$



$\mathcal{O}(\epsilon)$ perturbation equations

$h_{00}(r), \delta\varphi(r)$

$\delta\varphi(r)$

$h_{00}(r)$

- Tensor and scalar perturbations are coupled
- Challenge to disentangle the multipole and tidal moments numerically
- New methodology based on boundary conditions.

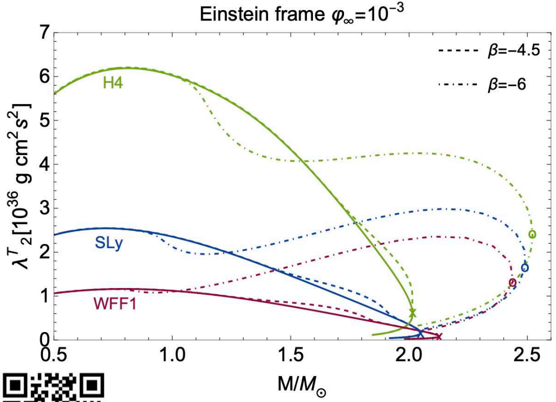
Check our paper!

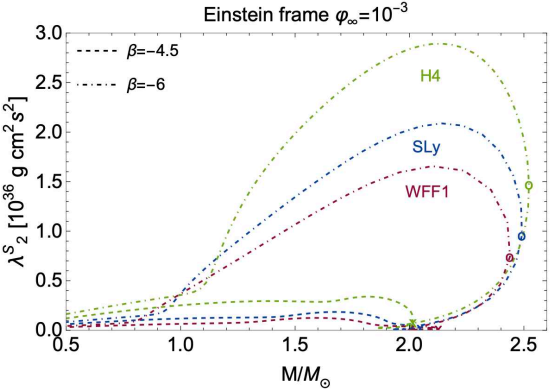
P. Pani and E. Berti (2014), arXiv:1405.4547 [gr-qc].

Case study: Neutron stars in scalar-tensor theories

Quadrupolar Love numbers

$$A(\varphi) = e^{\frac{1}{2}\beta\varphi^2}$$





Check our paper!

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Simulation of the gravitational-wave emission of core-collapse supernovae

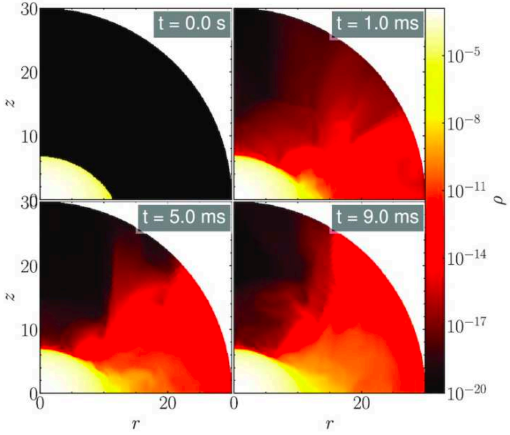
Arthur Offermans
KU Leuven
October 24, 2023

2 *Gmunu* solver

1-2-3D general-relativistic (magneto)hydrodynamics (GR(M)HD) (Cheong et al 2020, 2021, 2022, 2023; Ng et al 2023)

Example: rapidly rotating neutron star

Noticeable achievement: NS with $B \sim 10^{17}$G (Leung et al 2022)



Taken from (Cheong et al 2021)

Machine learning algorithms for the conservative-to-primitive conversion in relativistic hydrodynamics

Thibeau Wouters

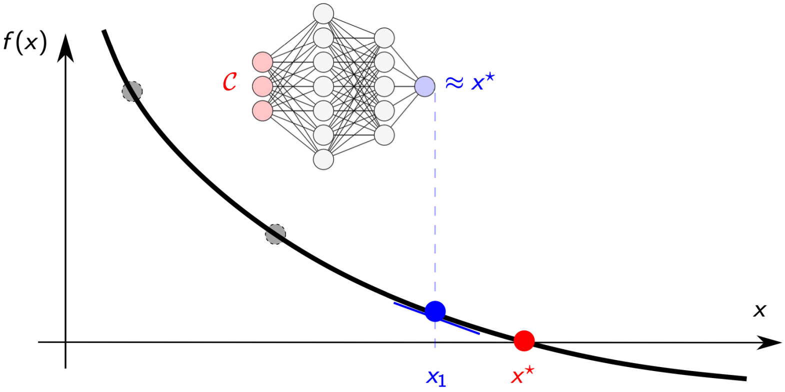
October 24, 2023

Utrecht University

KU LEUVEN

Hybrid approach: idea

Neural network gives an initial guess, to be refined with the root-finding algorithm.



Hybrid approach: proof of concept

Faster! Simulation time:

- Standard: (23.48 ± 0.54) seconds
- Hybrid, ReLU activation function: (18.84 ± 0.19) seconds
- Speed-up of $\sim 25\%$
- Same accuracy and robustness!

Astrophysics and Cosmology

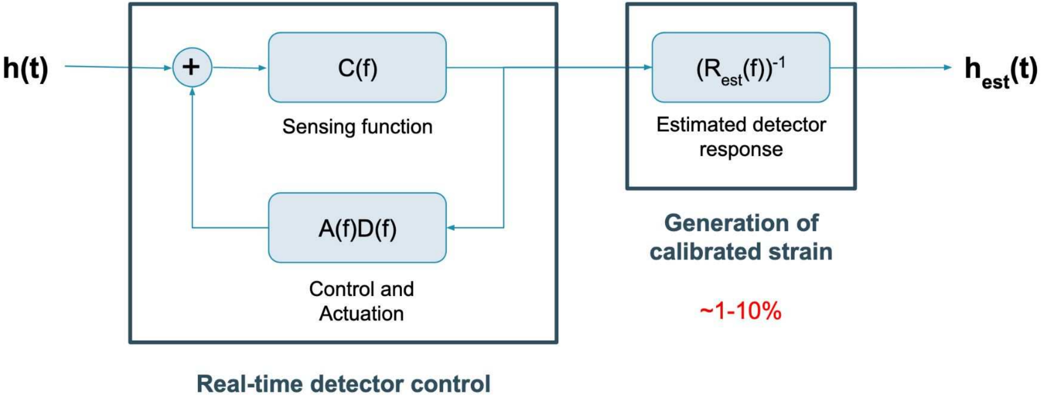
Parallel Session 2

KU LEUVEN

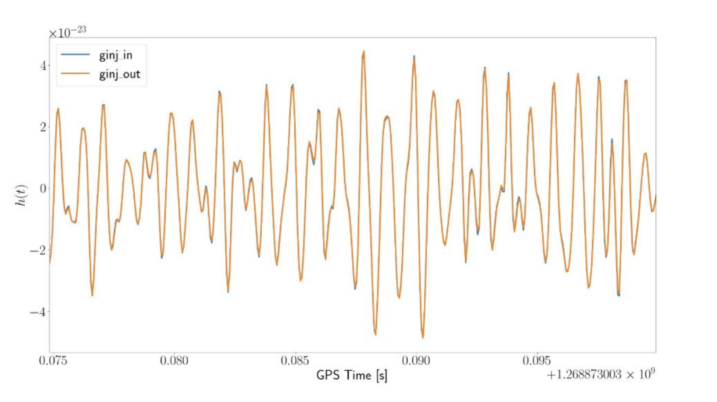
Impact of Physically Motivated Calibration Errors on Core-Collapse Supernova Searches

Milan Wils (KUL), Brad Ratto (UCSD), Michele Zanolin (ERAU), Marek Szczepańczyk (UF), Jeffrey Kissel (LHO), Gabriele Vedovato (INFN), Tjonnie G. F. Li (KUL)

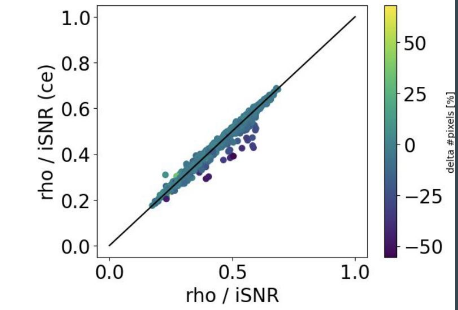
Calibration Uncertainty



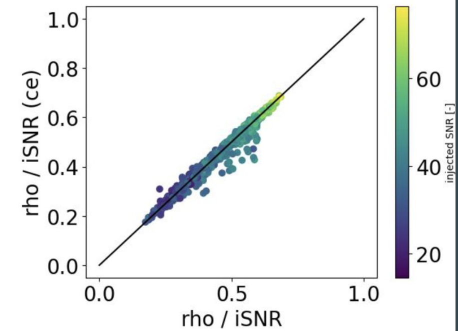
Results



×10^−23
ginj_in
ginj_out
4
2
0
−2
−4
h(t)
0.075
0.080
0.085
0.090
0.095
GPS Time [s]
+1.268873003 × 10^9



1.0
0.8
0.6
0.4
0.2
0.0
rho / iSNR (ce)
0.0
0.5
1.0
rho / iSNR
50
25
0
−25
−50
delta #pixels [%]



1.0
0.8
0.6
0.4
0.2
0.0
rho / iSNR (ce)
0.0
0.5
1.0
rho / iSNR
60
40
20
injected SNR [-]

Towards Precision Cosmology with Galaxy Catalogues

Gergely Dálya

Ghent University

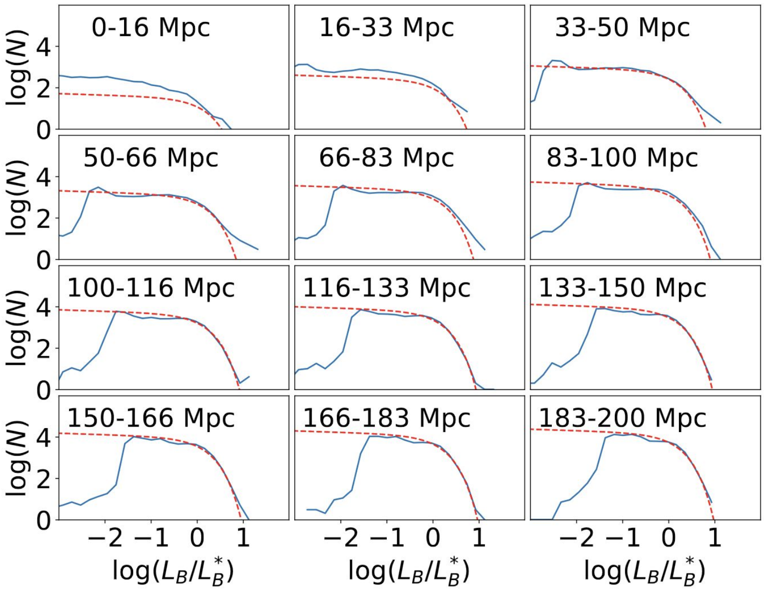
gergely.dalya@ugent.be

GHENT UNIVERSITY

BelGrav

October 24, 2023

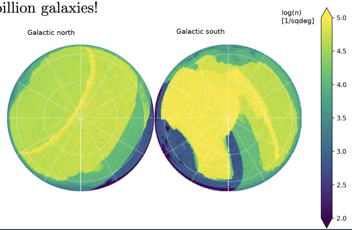
Missing galaxies, uncertainties in redshift, luminosity, etc.



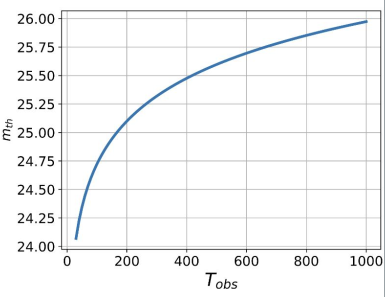
Some solutions

UpGLADE

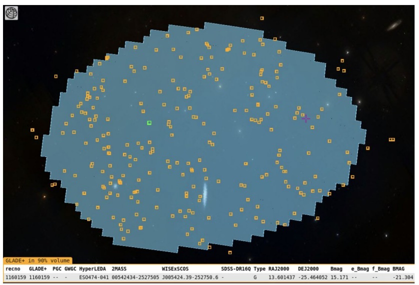
- LS DR8 + Duncan, LS DR9 + Zhou, LS DR10
- Pan-STARRS × CatWISE
- SkyMapper, Siena Galaxy Atlas, SDSS spectro-z
- 1 billion galaxies!



Targeted follow-up



GLADEnet



GHENT
UNIVERSITY

The luminosity of the darkness

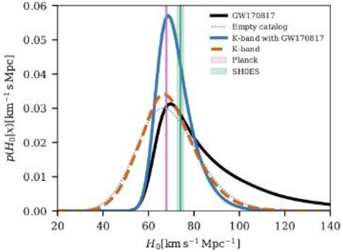
Schechter function in dark siren H_0 measurement

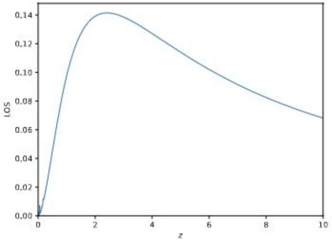
Cezary Turski, Maria Lisa Brozzetti

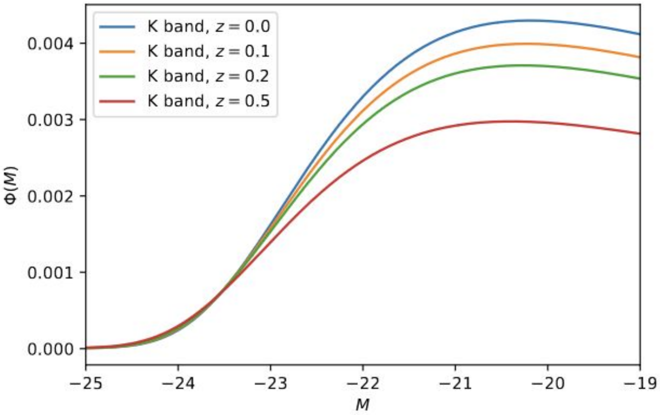
Belgian-Dutch Gravitational Wave Meeting

24.10.2023

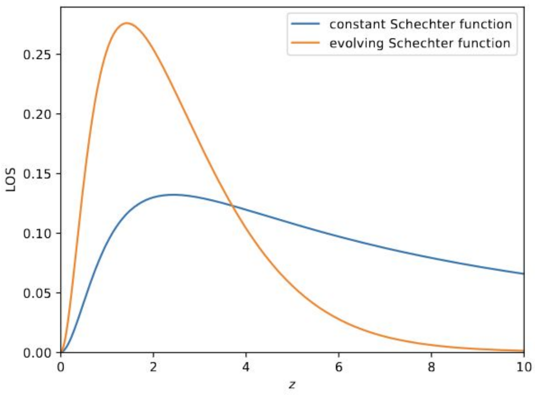
Abbott et al. 2021



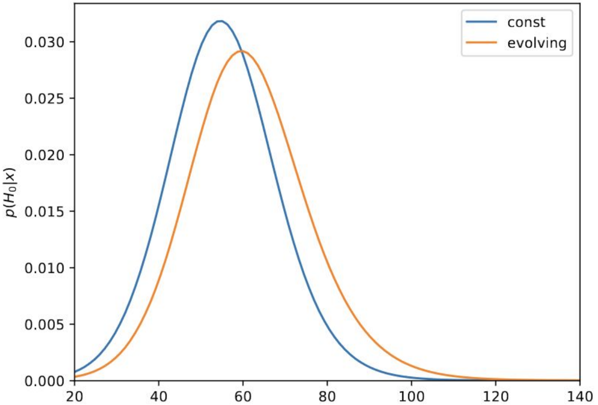




Results

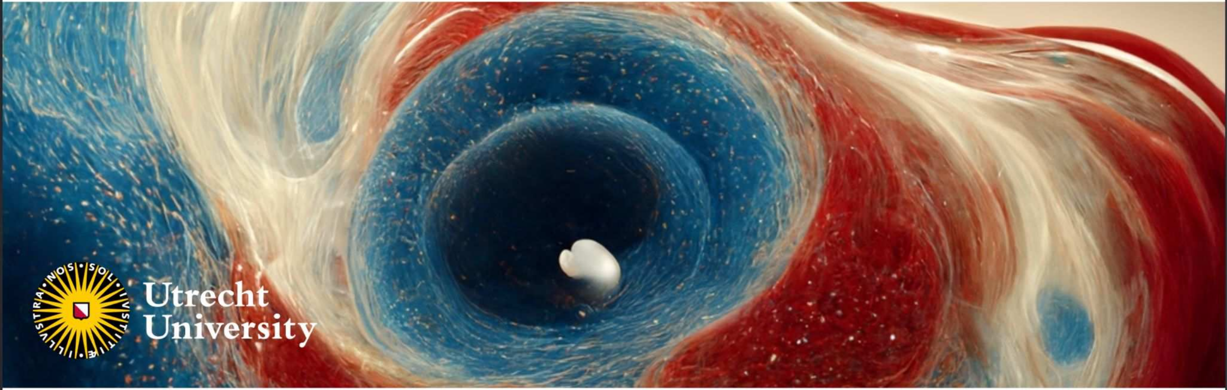


constant Schechter function
evolving Schechter function
LOS
0.00
0.05
0.10
0.15
0.20
0.25
0
2
4
6
8
10
z



const
evolving
$p(H_0|x)$
0.000
0.005
0.010
0.015
0.020
0.025
0.030
20
40
60
80
100
120
140

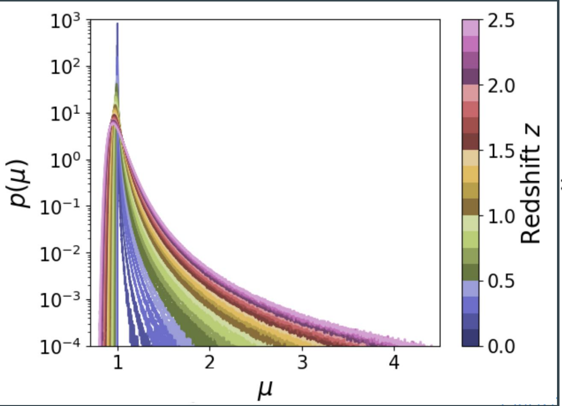
LENSING BIAS ON COSMOLOGICAL PARAMETERS FROM BRIGHT STANDARD SIRENS



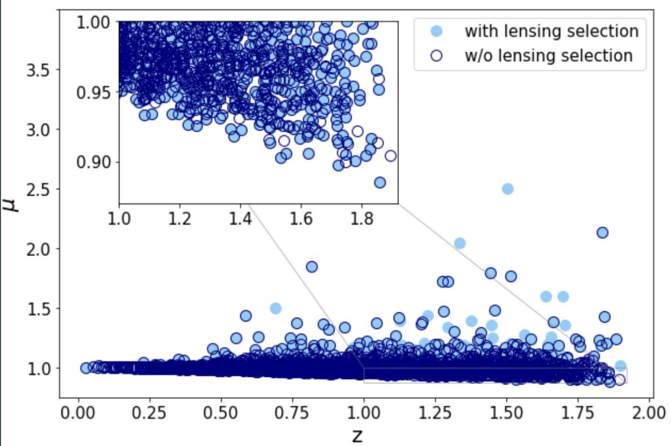
Sofia Canevarolo
in collaboration with Elisa Chisari

Based on arXiv:2310.12764

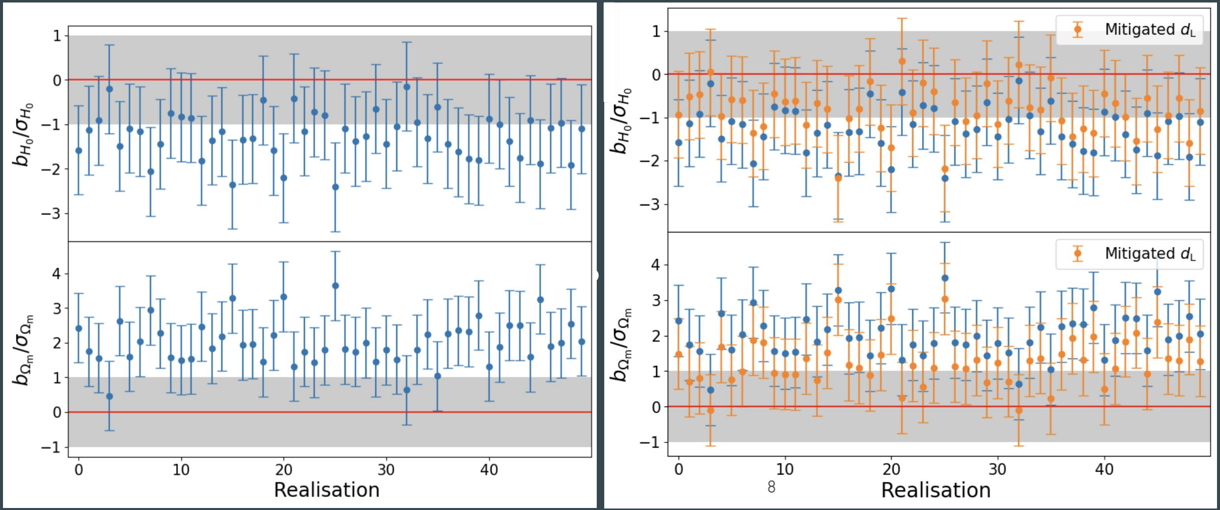
Belgian-Dutch Gravitational Wave Meeting 2023



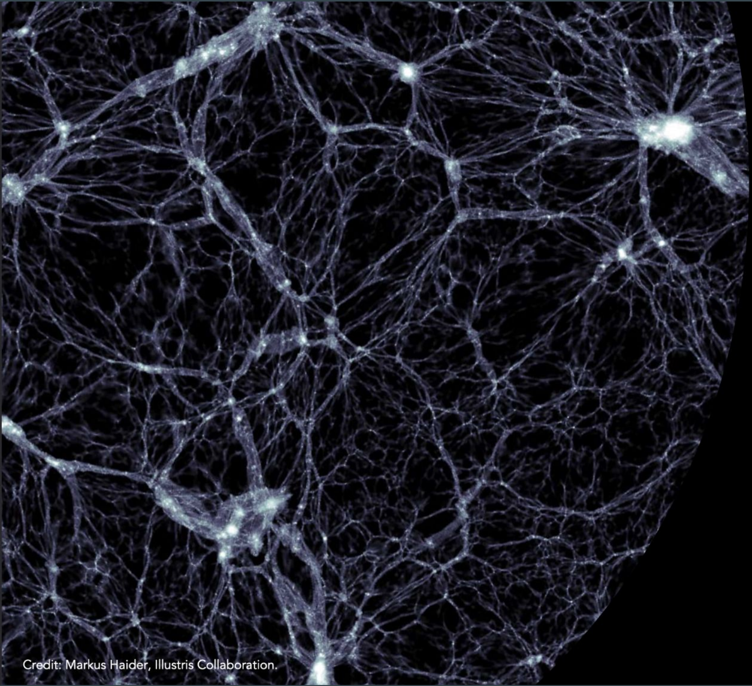
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$p(\mu)$
1
2
3
4
μ
2.5
2.0
1.5
1.0
0.5
0.0
Redshift z



with lensing selection
w/o lensing selection
3.5
3.0
2.5
2.0
1.5
1.0
μ
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
z
1.00
0.95
0.90
1.0
1.2
1.4
1.6
1.8



b_{H_0}/σ_{H_0}
$b_{\Omega_m}/\sigma_{\Omega_m}$
Realisation
Mitigated d_L
Mitigated d_L
b_{H_0}/σ_{H_0}
$b_{\Omega_m}/\sigma_{\Omega_m}$
8
Realisation



Credit: Markus Haider, Illustris Collaboration.

Number counts of GW in ΛCDM and Scalar-Tensor Theories

Anna Balaudo

In collaboration with:

Mattia Pantiri

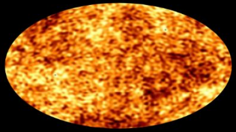
Alessandra Silvestri

Sterrewacht Leiden

Universiteit Leiden
The Netherlands

Is the Universe homogeneous and isotropic?

Primordial perturbations

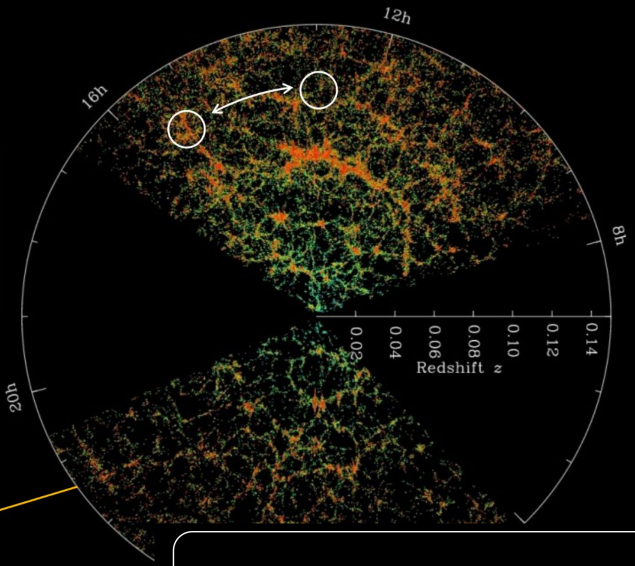


Cosmological model →

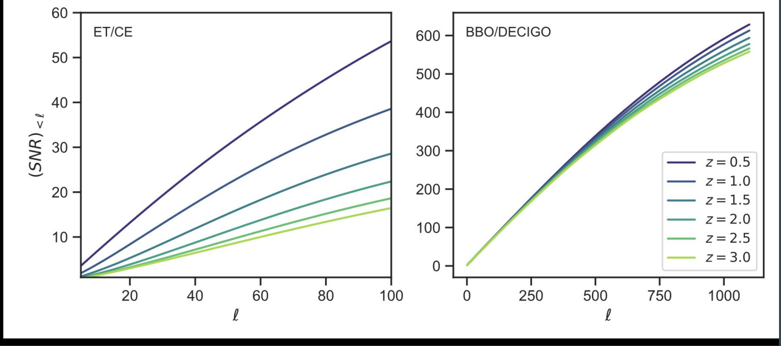
Theory ?

Data

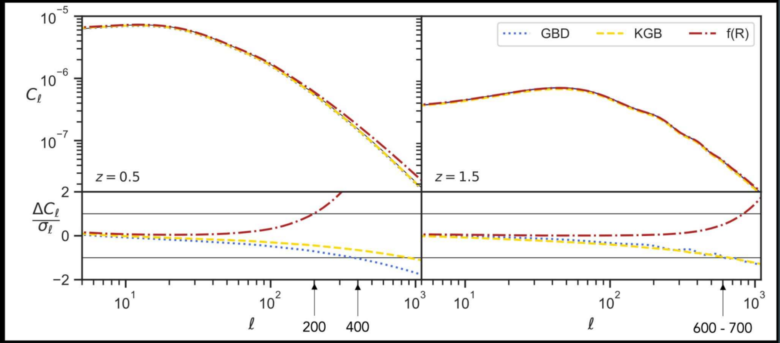
$$\hat{\Delta}(D,\hat{n}) \equiv \frac{N(D,\hat{n}) - \bar{N}(D)}{\bar{N}(D)}$$



$$\hat{\Delta}(D,\hat{n}) \equiv \frac{N(D,\hat{n}) - \bar{N}(D)}{\bar{N}(D)} = \text{density fluctuations} + \text{relativistic effects}$$



Could be detected in next-generation detectors



Data analysis

Parallel Session 1

Gravitational-wave parameter estimation with relative binning: Inclusion of higher-order modes and precession, and applications to lensing and third-generation detectors

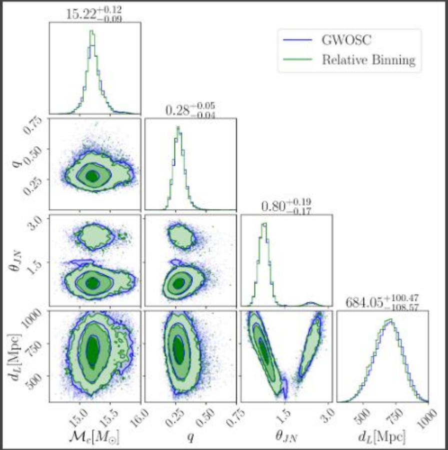
H. Narola, J. Janquart, Q. Meijer,
K. Haris, C. V. D. Broeck

arXiv:2308.12140

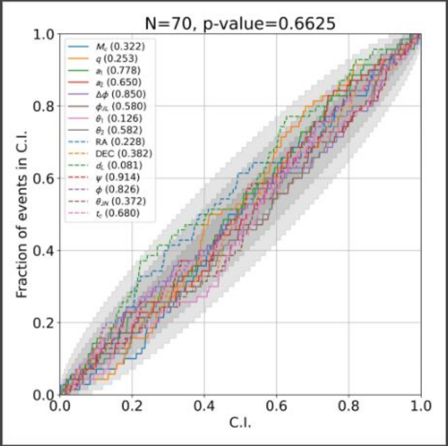
Universiteit Utrecht

Results

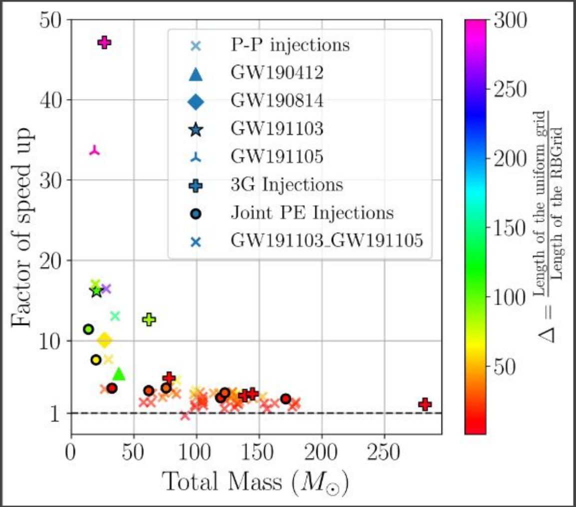
GW190412



Injections



Speed Up



P-P injections
GW190412
GW190814
GW191103
GW191105
3G Injections
Joint PE Injections
GW191103_GW191105
Factor of speed up
Total Mass ($M_\odot$)
$\Delta = \frac{\text{Length of the uniform grid}}{\text{Length of the RBGrid}}$
50
40
30
20
10
1
0
50
100
150
200
250
300

UNIVERSITEIT VAN AMSTERDAM

Sequential simulation based inference for gravitational waves

Uddipta Bhardwaj
GRAPPA, University of Amsterdam
u.bhardwaj@uva.nl

Collaborators


James Alvey


Samaya Nissanke


Christoph Weniger

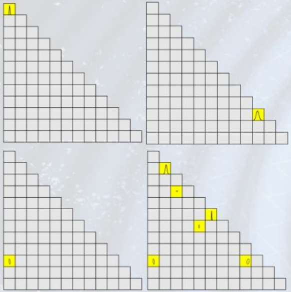

Ben Miller

Based on **2304.02035, 2308.06318**

PEREGRINE
Gravitational Wave Parameter Inference with Neural Ratio Estimation

TMNRE performs precision analysis sequentially

(Marginal) Neural Ratio Estimation $r(d;\theta) = \dfrac{p(x|\theta)}{p(d)} = \dfrac{p(\theta|d)}{p(\theta)} = \dfrac{p(d,\theta)}{p(d)p(\theta)}$



Binary classification task: Given a pair (θ, d), did θ generate d ?

Class 1: Matching (data, parameter) pairs

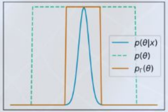
(🐱, cat) (🐈, dog)

(⭐, star)

Class 0: Scrambled (data, parameter) pairs

(🐱, dog) (🐈, star)

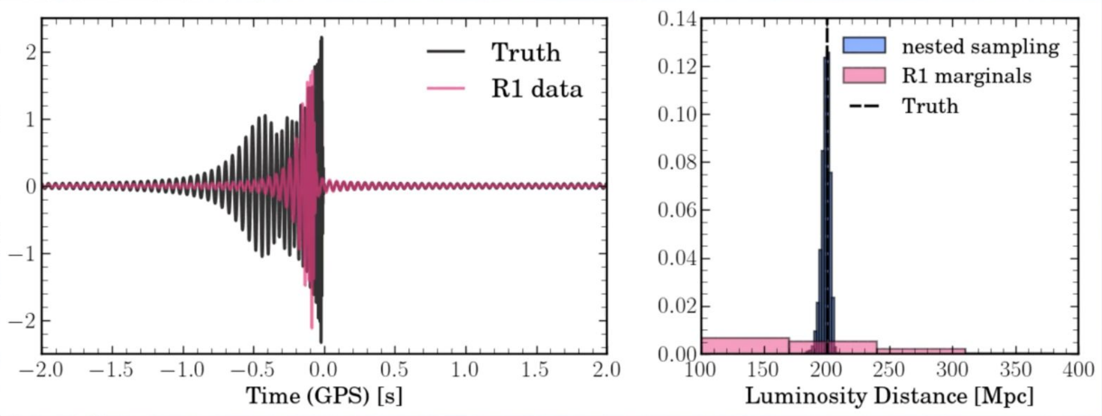
(⭐, cat)



Truncated **Marginal Neural Ratio Estimation (TMNRE)**

swyft : **Miller et al. (2021, 2022)**
arXiv:2011.13951
arXiv:2107.01214
Slide credit: C. Weniger

Sequential SBI for GW parameter inference



- ~ 700k simulations constitute training data over subsequent TMNRE rounds
- Achieve precision via truncation onto HPD regions

~98% reduction in waveform evaluations!!

- ~ 45 million waveform computations for dynesty!

Detection of anomalies amongst LIGO's glitch populations with autoencoders

Melissa Lopez

m.lopez@uu.nl

ArXiv: 2310.03453

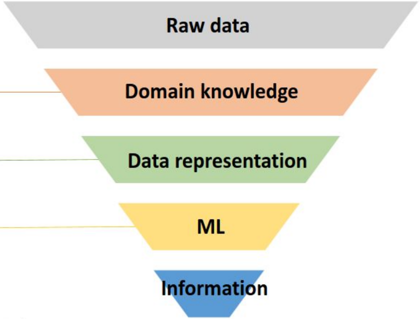
Encode, encode, encode

How can we reduce a 10^6 auxiliary channels (ac)?

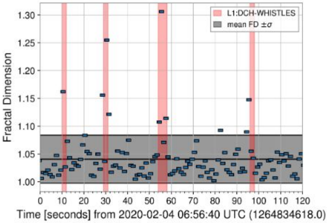
Select safe channels, i.e.not affected by GW (350 ac)

Encode with fractal dimension, i.e. measure complexity of the data

Use convolutional autoencoders



- M. Cavaglia 2022 → 1h of data encoded in 1h
- Our work → 1h of data encoded in 11s



Robin van der Laag (UU)
Expert in high performance computing

Paloma Laguarta (UM)
Expert in ML
PhD at LHCb

Results of compressed data

In total 177 anomalies were found, which constitute 6,6% of the data.

- **Anomalous whistles (49):**
  - 45% unknown morphologies, 28% misclassifications, 27% overlaps.
- **Anomalous Tomtes (57):**
  - 32% unknown morphologies, 21% misclassifications, 47% overlaps.
- **Anomalous Scattered Lights (71):**
  - 28% unknown morphologies, 72% misclassifications, 1 overlap.

SCAN ME

ArXiv: 2310.03453

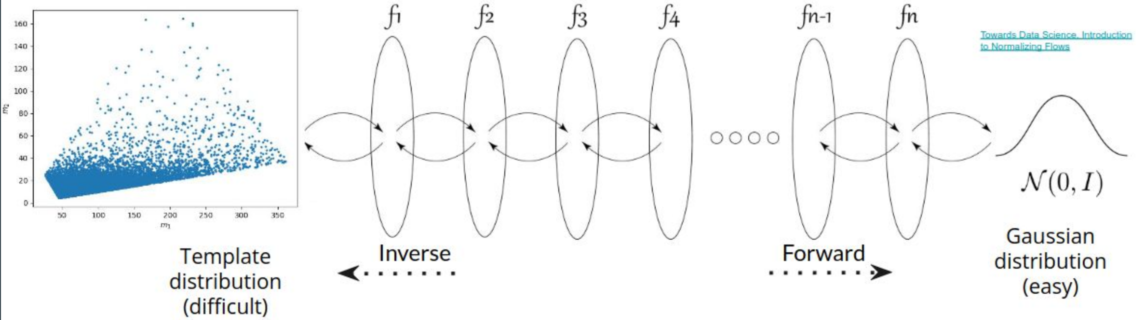
A precessing template bank

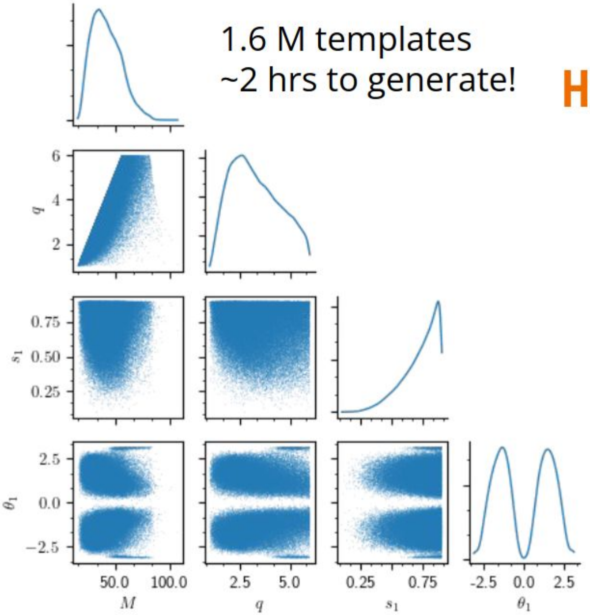
Stefano Schmidt

Belgian-Dutch Gravitational Wave Meeting 2023

Let's make a precessing bank (part II)

Sampling from the volume with Normalizing Flow





1.6 M templates
~2 hrs to generate!

How does the bank look like?

Parameter space

$m_1, m_2 \in [8, 70]\ M_\odot$
$q \in [1, 6]$
$s_1 \in [0, 0.99]$
$\theta_1 \in [-\pi, \pi]$
$s_2 \in [-0.99, 0.99]$
$\iota \in [0, \pi]$

$s_{1x} = s_1 \sin(\theta_1)$
$s_{1y} = 0$
$s_{1z} = s_1 \cos(\theta_1)$

Belgian-Dutch Gravitational Wave meeting 2023, 23rd-24th October 2023, Maastricht, The Netherlands

Jointly Estimating multiple Components and Population Properties of Astrophysical Gravitational-Wave Background

Presented by

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in collaboration with

Jishnu Suresh

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Université catholique de Louvain, Louvain-la-Neuve, B-1348, Belgium

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arXiv:2310.05823

Summary

- Search for a Gaussian, stationary, unpolarised, isotropic SGWB, relaxing the hypothesis of a single component being present at a time
- Method extended to astrophysical SGWBs and implications about ensemble properties
- Analysis performed over the data from the first three LIGO-Virgo-KAGRA observing runs for $\alpha = 0, 2/3, 2, 3, 4$, assuming a power law SGWB in the 20-100 Hz band of the analysis
- No signal was found, 95% Bayesian upper limits on the Ω_α were drawn
- Implications about astrophysical ensemble properties for CBC ($\alpha = 2/3$), r-mode ($\alpha = 2$), and magnetar ($\alpha = 4$) SGWBs: limits not yet very informative or competitive with the existing ones
- Important take away from the injection study: this method will avoid bias and overestimating the components when getting closer to a detection (assuming power-law assumption holds)
- Possible improvements: need to go beyond the simple PL approximation to allow more flexibility (e.g., broader frequency range and remove degeneracy for CBC subpopulations)

Stochastic gravitational wave background constraints from Gaia Data Release 3

Santiago Jaraba (IFT, Madrid)

Belgian-Dutch Gravitational Wave Meeting, 24th October 2023

Based on S. Jaraba, J. García-Bellido, S. Kuroyanagi, S. Ferraiuolo, M. Braglia, MNRAS 524 (2023) 3, 3609-3622

Instituto de Física Teórica UAM-CSIC
Universidad Autónoma de Madrid
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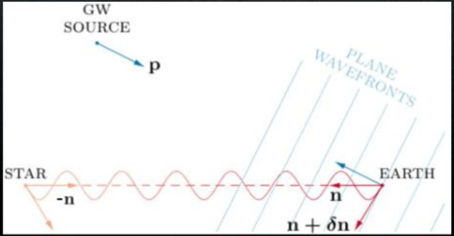
Gravitational waves from astrometry

- Studied in the 1980s and 90s (E. V. Linder 1986, Braginsky et al. 1990, Pyne et al. 1995, Gwinn et al. 1996, etc.).
- Recent review by Book & Flanagan 2010, arXiv:1009.41920.
- We observe light from distant stars.
- The passage of a GW can alter the observed position.



D. P. Mihaylov et al., arXiv:1804.006608 (modified to match Book&Flanagan notation)

Results

- For VLBA and VLBA+Gaia datasets, we worsen a bit the results by Darling et al. (0.0064 and 0.011).
  - Expected due to the differences in our works.
- Still, VLBA places better constraints than Gaia DR3.
- Also expected due to the much better resolution in VLBA, caused by the larger observing period (22.2 years vs 2.84).

Dataset	$\sqrt{P_2}$ (μas/yr)	$h_{70}^2\Omega_{\rm GW}$	$h_{70}^2\Omega_{\rm GW}^{\rm up}$ (95%)
Masked	12.51(1.81)	0.069(0.021)	0.114
Pure	23.15(2.01)	0.235(0.040)	0.295
Astrometric	10.13(1.73)	0.045(0.017)	0.089
Intersection	9.53(1.73)	0.040(0.017)	0.087
VLBA	2.73(1.23)	0.0033(0.0056)	0.024
VLBA+Gaia DR1	5.30(1.36)	0.0123(0.0077)	0.034

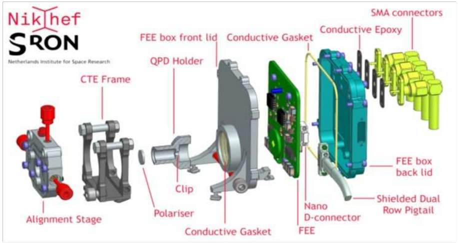
Instrumentation

Parallel Session 1

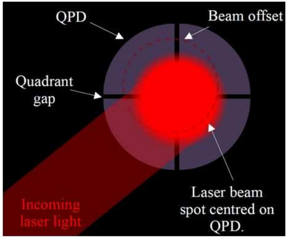
The Eyes of LISA

T. Mistry, M.v. Beuzekom, N.v. Bakel, R. Cornelissen, M. Adams, G. Vissier, J. Zand, P. Dieleman, M. Frericks, P. Laubert, R. Wanders, L. Dubbeldam, G. Aitink, M. Siegl

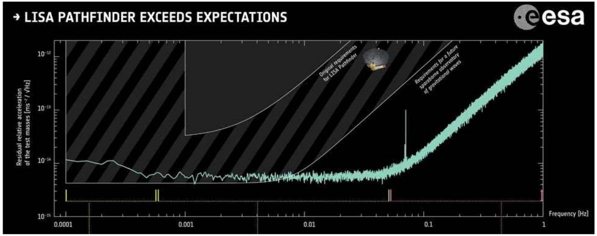
- Longer measuring timescale (~30 days instead of <1s)
- Process data on Earth with Time Delay Interferometry (TDI) algorithm
- Challenges:
  - Three interferometers on each 35cm optical bench
  - Need for diodes with extra thick drift layers and extremely low doping → challenging for industry
  - Photodiode housing needs to include alignment hardware, isolation from thermal and vibrational effects and antenna radiation,…



The eyes of LISA = Quadrant Photo-Receivers (QPR)

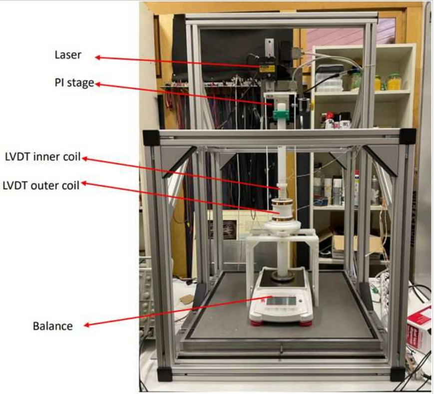


Signal detection and diagnostics performed by the same sensor



Kumar Akhil Kukkadapu
PengboLi
MichielYzewyn

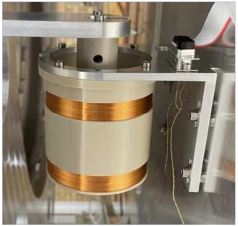
Position sensors and actuators for ETpathfinder

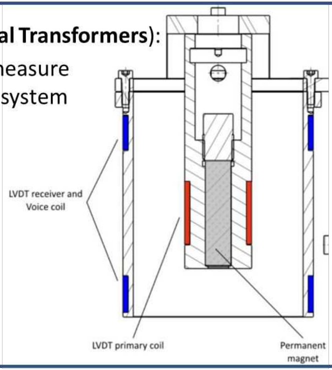


LVDT setup

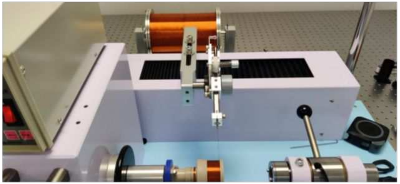
LVDT (**Linear Variable Differential Transformers**):

Use magnetic induction to measure displacement of suspension system





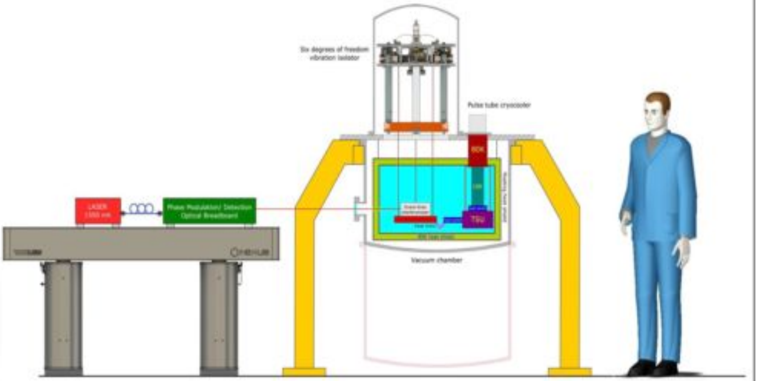
Coils assembled in Maastricht



← Transverse motion and voice coil force measurements are done in Antwerp

Cryogenic Coating Thermal Noise direct measurement

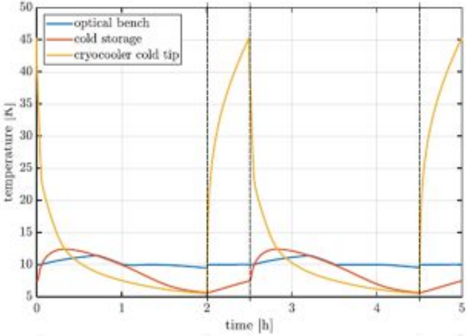
- Koen Lotze, Enrico Porcelli, Enzo N. Tapia S. Martin, Alessandro Bertolini, Marcel ter Brake, Rogier Elsinga, Eric Hennes, Stefan Hild, Michiel van Limbeek, Fabian Meylahn, Matteo Tacca, Cris Vermeer, Benno Wilke

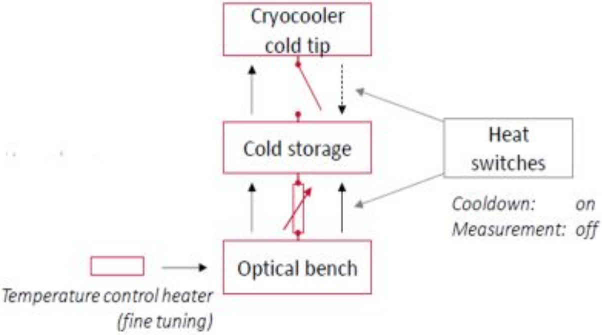


The facility will be available to groups interested in having direct direct thermal noise measurements.

Heat switches to unlink the cryocooler from the cold storage.

Cryogenic Technology



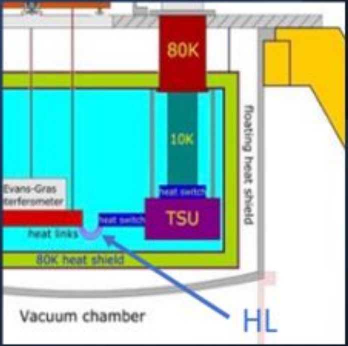


Heat switches

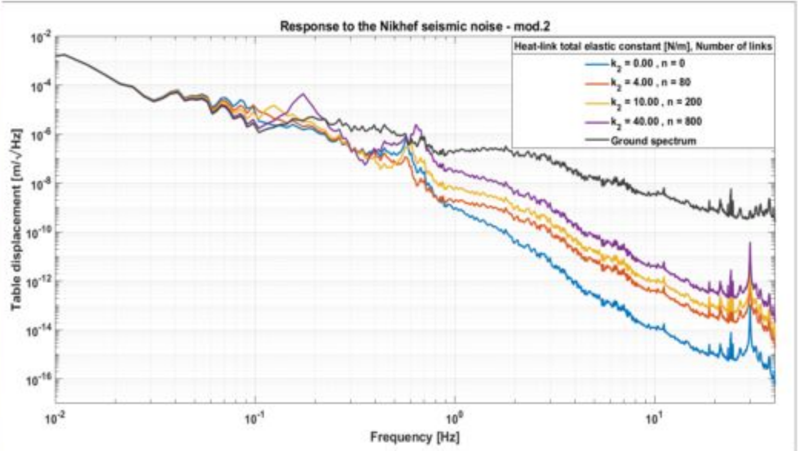
Koen Lotze

Seismic Attenuation System
(Enrico Porcelli)

- Suspended bench, thermalized via a soft heat link.
- Vibrations coming from the heat link.

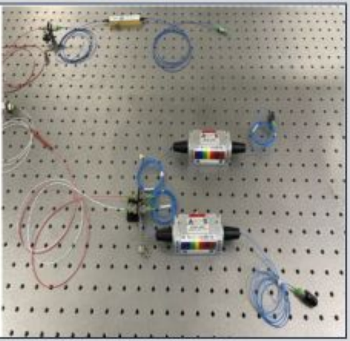


n=200**wires per HL** is the best compromise to have a good ground isolation and Thermal Resistance at the same time.

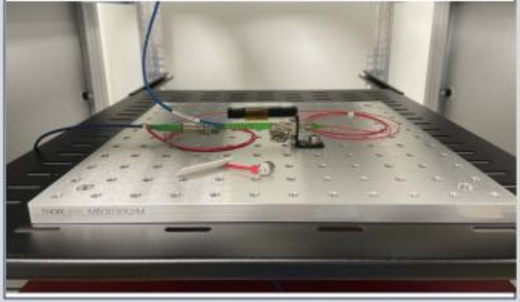


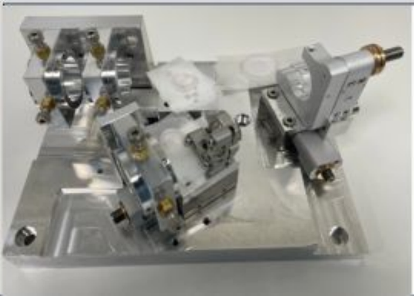
Optical setup (Enzo Tapia)

Electro-optic Modulator (EOM) and Acousto-optic Modulators (AOMs) installed in lab:



Main Laser and Faraday Isolator: 1550nm
Main laser with 0.1-2W Output Power.





Optical Setup at Nikhef Lab

Instrumentation

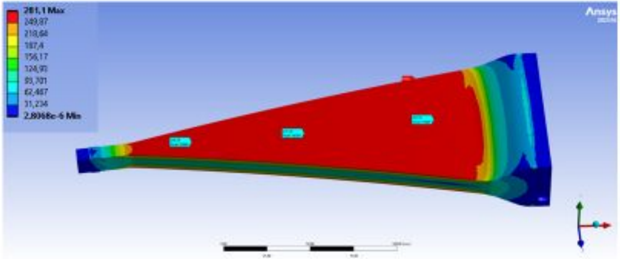
Parallel Session 2

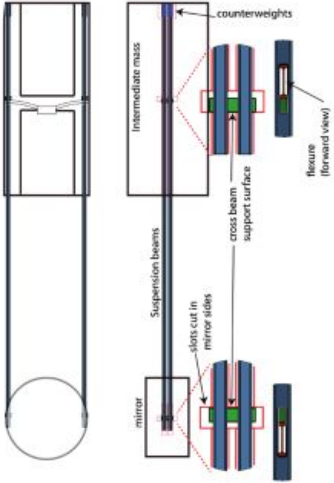
VERTICAL Crystalline Silicon Blades-Suspension system for the Einstein Telescope

Silicon rods used for suspensions are longitudinally very stiff.

- ➡ Vertical compliance makes assembly of the suspension easier
- ➡ Lowering the vertical natural frequency reduces the impact of vertical mirror thermal noise

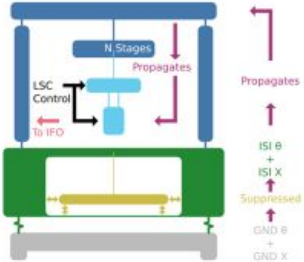
Fine-tune the blade's geometry for improved lower mechanical stress, lower resonance frequencies, and reduced thermal noise.

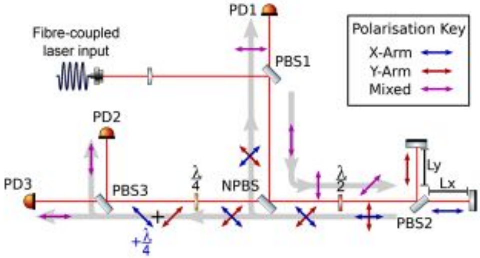




Updates from the Omnisense project

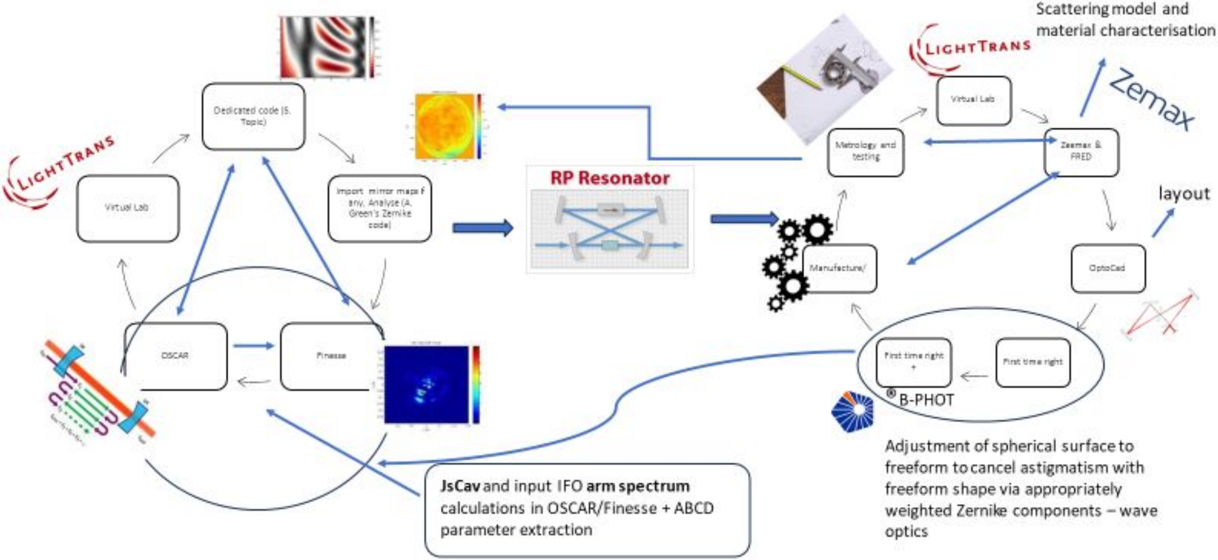
- Active platform with a 6D sensor to improve seismic isolation at low frequencies
- Sensitive to tilt



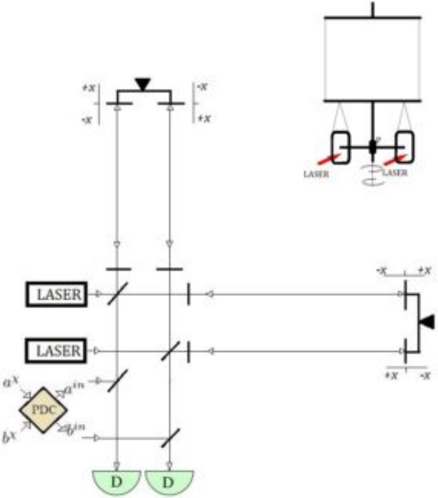


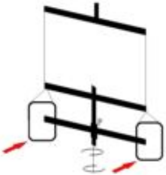
- Homodyne Quadrature Interferometers for readout
- Active isolation may be needed for ET

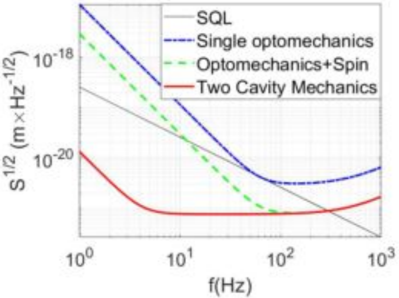
Software ecosystem for simulation and design of I/O GW Interferometer cavities



Back-Action Evading Measurement in Gravitational Wave Detectors to Overcome Standard Quantum Limit, Using Negative Radiation Pressure







- Back-action evading by probing two mirrors
- Negative radiation pressure coupling between the field and the end mirror
- Promises beating SQL over wide frequency range