Belgian-Dutch Gravitational Wave Meeting 2023

Report of Contributions

Contribution ID: **1** Type: **not specified**

Welcome

Monday, 23 October 2023 09:30 (10 minutes)

Presenter: HILD, Stefan

Contribution ID: **4** Type: **Talk**

First observational constraints on the GW-AGN connection through spatial correlation analysis.

Monday, 23 October 2023 14:30 (15 minutes)

Despite the increasing number of GW detections, the astrophysical origin of the Binary Black Hole (BBH) mergers detected by the LIGO and Virgo interferometers remains elusive. A promising formation channel for these BBHs is inside accretion discs around supermassive black holes, that power AGN. Investigating the spatial correlation between the positions of these potential host environments and the localisation volumes of detected BBHs allows to put constraints on the GW-AGN connection. In this talk I will present how we used this approach to obtain the first observational constraints of the fractional contribution of the so-called AGN channel to the total stellar-mass BBH merger rate. We have found that the fraction of the detected mergers originated in AGN brighter than $10^{45.5}\,\mathrm{erg\,s^{-1}}$ ($10^{46}\,\mathrm{erg\,s^{-1}}$) cannot be higher than 0.49 (0.17) at a 95 per cent credibility level.
Our upper limits imply a limited BBH merger production efficiency of
the brightest AGN, while most or all GW events may still come from lower
luminosity ones. Alternatively, the AGN formation path for merging stellar-mass BBHs may be actually overall subdominant in the local Universe.

Primary author: VERONESI, Niccolò (Leiden Observatory)

Co-authors: Dr ROSSI, Elena (Leiden Observatory); Dr VAN VELZEN, Sjoert (Leiden Observatory)

Presenter: VERONESI, Niccolò (Leiden Observatory)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **5** Type: **Talk**

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

Tuesday, 24 October 2023 11:45 (15 minutes)

We propose a novel scheme how to obtain quantum back action evading measurement on a gravitational wave detector, by introducing negative radiation pressure coupling between the field and the end mirror. The scheme consists of replacing the end mirror with a double-faced one and adding another optical cavity next to it. The measurement is performed by sending a two-mode squeezed vacuum to both cavities and detecting the output through heterodyne detection. Compared to the previously proposed hybrid negative mass spin-optomechanical system in Phys. Rev. Lett. 121, 031101 (2018), we see that our scheme is capable to suppress back action noise by more than nearly two orders of magnitude in the lower frequency region. Overall, the setup has been able to squeeze the output noise below the standard quantum limit, with more efficiency. In addition, the scheme has also proven to be beneficial for reducing eh thermal noise by a significant amount. We confirm our result by a numerical analysis and compared with previous proposals.

Primary author: AGASTI, souvik (University of Hasselt)

Presenter: AGASTI, souvik (University of Hasselt)

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **6** Type: **Talk**

Binary star channels of stripped-envelope supernovae.

Monday, 23 October 2023 14:15 (15 minutes)

Population synthesis is a crucial tool for studying the predictions of binary evolution models on many astrophysical objects and transients of interest. In this study, we use the population synthesis code COMPAS to constrain the uncertain physics of binary mass transfer, using a locally complete sample of stripped-envelope supernovae. We argue that current evolutionary models are surprisingly successful at reproducing the intrinsic supernova rates, and highlight the model parameters which are the most influential and thus deserve closer investigation. The methodology used can be extended to any observationally complete sample of post-interaction binary systems or associated transients. These constraints are an important step in reducing the large error bars of population synthesis predictions for coallescing compact binaries.

Primary author: WILLCOX, Reinhold (KU Leuven)

Presenter: WILLCOX, Reinhold (KU Leuven)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **7** Type: **Talk**

Can the gravitational wave background feel wiggles in spacetime?

Tuesday, 24 October 2023 09:00 (15 minutes)

Recently the international pulsar timing array collaboration has announced the first strong evidence for an isotropic gravitational wave background (GWB). We propose that rapid small oscillations (wiggles) in the Hubble parameter would trigger a resonance with the propagating gravitational waves, leaving unique signatures in the GWB spectrum as sharp resonance peaks/troughs. The proposed signal can appear at all frequency ranges and is common to GWBs with arbitrary origin. The resonant signal can appear as a trough only when the GWB is primordial, and its amplitude will also be larger by one perturbation order than in the non-primordial case. These properties serve as a smoking gun for the primordial origin of the observed GWB. We showcased the viability of the signal to near future observations using the recent NANOGrav 15yr data.

Primary author: YE, Gen (Lei)

Co-author: Dr SILVESTRI, Alessandra (Leiden University)

Presenter: YE, Gen (Lei)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **8** Type: **Talk**

Follow-up Analyses to the O3 LIGO-Virgo-KAGRA Lensing Searches

Monday, 23 October 2023 16:00 (15 minutes)

Along their path from source to observer, gravitational waves may be gravitationally lensed by massive objects leading to distortion in the signals. Searches for these distortions amongst the observed signals from the current detector network have already been carried out, though there have as yet been no confident detections. However, predictions of the observation rate of lensing suggest detection in the future is a realistic possibility. Therefore, preparations need to be made to thoroughly investigate the candidate lensed signals. In this work, we present some follow-up analyses that could be applied to assess the significance of such events and ascertain what information may be extracted about the lens-source system by applying these analyses to a number of O3 candidate events, even if these signals did not yield a high significance for any of the lensing hypotheses. These analyses cover the strong lensing, millilensing, and microlensing regimes. Applying these additional analyses does not lead to any additional evidence for lensing in the candidates that have been examined. However, it does provide important insight into potential avenues to deal with high-significance candidates in future observations.

Primary author: JANQUART, Justin

Presenter: JANQUART, Justin

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **9** Type: **Talk**

Coating thermal noise direct measurement at cryogenic temperature

Tuesday, 24 October 2023 09:30 (15 minutes)

Currently, the design sensitivity of the second generation Gravitational-Wave (GW) detectors is limited in the low and mid frequency range by Thermal Noise (TN) and Seismic Noise (SN).
Major improvements in GW instrumentation science are expected from the Thermal Noise (TN) reduction in the mid-frequency range of the detectors, achievable also by cooling down the mirrors to 10K.
In order to select the coating material that are intended to be used in the third generation of detectors, the TN of new coatings should be directly measured using an interferometric method in a cryogenic environment. A setup enabling this kind of characterization is under development.
In this talk we will present the design and the status of the isolation system identified to reduce the ground vibration that can affect the measurements.

Primary author: PORCELLI, Enrico (Nikhef)

Presenter: PORCELLI, Enrico (Nikhef)

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **10** Type: **Talk**

Optical setup for coating thermal noise measurements

Tuesday, 24 October 2023 09:45 (15 minutes)

One of the fundamental limitations to the sensitivity of current gravitational wave (GW) detectors, especially in their mid-frequency range, is Brownian thermal noise. This noise source affects not only mirror coatings but also mirror substrates and suspensions, potentially limiting the sensitivity of third-generation GW detectors.

To overcome these limitations, the plan is to replace current fused-silica mirrors with silicon mirrors and cool them to 10K, which is a new material and operating temperature for GW detectors. This endeavour involves two pivotal aspects: the direct measurement of mirror thermal noise at cryogenic temperatures and the characterization of coating materials and techniques for the next-generation detectors.

This document presents an optical setup designed for measuring coating thermal noise (CTN), which manifests as fluctuations of length of an optical cavity due to the remaining motion present in the material of the coating of the mirrors. To measure these fluctuations, we apply the fluctuation-dissipation theorem to our setup.

This optical setup consists of a 1550 nm laser beam split into three beams, with two shifted in frequency using Amplitude Optical Modulators (AOMs). Control loops stabilize the laser frequency, stabilize the frequency-shifted beams, and lock the co-resonating modes within the cavity. The optical setup places a sample mirror within a high-Finesse optical cavity that allows the co-resonance of three modes: the fundamental laser mode (TEM00) and two higher-order modes (TEM02 and TEM20). CTN manifests as fluctuations in the resonant frequencies of the latter two higher-order modes.

The key distinction is that the CTN sensed by TEM02 differs from that sensed by TEM20 because they explore different areas of the mirror coating. In our experiment, CTN is determined by analysing the beat note signal between the resonant frequencies of TEM02 and TEM20. We've focused on the preparation and simulations to refine our setup. These simulations are important to ensure the experiment's success and help us to tackle potential problems.

Initially, this cavity will operate at room temperature and in-vacuum. Once we can demonstrate its functionality, our plan is to transition it to in-vacuum conditions at cryogenic temperatures.

The final goals of this experiment are to determine if direct measurement of coating thermal noise is feasible for third-generation GW detectors, identify optimal coating materials and techniques for maximizing detector sensitivity.

Primary authors: Dr BERTOLINI, Alessandro (Nikhef); TAPIA, Enzo; TACCA, Matteo

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **11** Type: **Poster**

”Investigating test mass parameters for the Einstein Telescope interferometer ”

Tuesday, 24 October 2023 13:30 (5 minutes)

“The ambitious Einstein Telescope (ET) project aims to prove an up-close examination of gravitational waves originating from sources near the birth of the Universe. This study's objective is to investigate parameter specifications for the interferometer's mirrors, including the level of surface distortion necessary for the detector to operate at the required sensitivity.
To achieve this, we start with a suitable set of surface maps from Advanced LIGO and Advanced Virgo as a foundation. These maps are used to generate virtual mirror maps representations, which in turn become the basis for optic simulations representing ET's behavior. The ultimate goal is to refine the mirror requirements and optimize the pathway for ET's mission.”

Primary author: Ms BIANCHI, Antonella (Nikhef/VU)

Co-authors: Mr FREISE, Andreas (Nikhef/VU); Ms GREEN, Anna C. (Nikhef); Mr BROWN, Daniel D. (University of Adelaide); Mr PERRY, Jonathan (Nikhef/VU); Mr VAN DER KOLK, Miron (Nikhef); Mr SALLÈ, Mischa (Nikhef); Mr MAGGIORE, Riccardo (Nikhef)

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **12** Type: **Talk**

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

Tuesday, 24 October 2023 09:15 (15 minutes)

We know very little about the first few seconds of the universe, beyond the very successful Big Bang nucleosynthesis. In those first instants, First Order phase transitions in the early plasma could have taken place and reshape the content of the plasma and spacetime. For the computation of baryogenesis, gravitational waves, dark matter production or even possibly PBH production, the asymptotic velocity of the bubble wall is a crucial parameter. In this talk we will see how a proper quantization of particles changing mass across the bubble wall can help to take into account the pressure on the bubble wall from transverse and from longitudinal modes.

Primary author: VANVLASSELAER, Miguel (VUB)

Presenter: VANVLASSELAER, Miguel (VUB)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **13** Type: **Talk**

Bayesian inference of binary black holes with inspiral-merger-ringdown waveforms using two eccentric parameters

Monday, 23 October 2023 16:30 (15 minutes)

Orbital eccentricity is a crucial physical effect to unveil the origin of compact-object binaries detected by ground- and spaced-based gravitational-wave (GW) observatories. Here, we perform for the first time a Bayesian inference study of inspiral-merger-ringdown eccentric waveforms for binary black holes with non-precessing spins using two (instead of one) eccentric parameters: eccentricity and relativistic anomaly. We employ for our study the multipolar effective-one-body (EOB) waveform model SEOBNRv4EHM, and use initial conditions such that the eccentric parameters are specified at an orbit-averaged frequency. We show that this new parametrization of the initial conditions leads to a more efficient sampling of the parameter space. We also assess the impact of the relativistic-anomaly parameter by performing mock-signal injections, and we show that neglecting such a parameter can lead to significant biases in several binary parameters. We validate our model with mock-signal injections based on numerical-relativity waveforms, and we demonstrate the ability of the model to accurately recover the injected parameters. Finally, using standard stochastic samplers employed by the LIGO-Virgo-KAGRA Collaboration, we analyze a set of real GW signals observed by the LIGO-Virgo detectors during the first and third runs. We do not find clear evidence of eccentricity in the signals analyzed, more specifically we measure $e^{\mathrm{GW150914}}_{\mathrm{gw,\,10Hz}} = 0.08^{+0.09}_{-0.06}$, $e^{\mathrm{GW151226}}_{\mathrm{gw,\,20Hz}} = 0.05^{+0.05}_{-0.04}$, and $e^{\mathrm{GW190521}}_{\mathrm{gw,\,5.5Hz}} = 0.15^{+0.12}_{-0.12}$.

Primary author: RAMOS-BUADES, Antoni (Nikhef)

Presenter: RAMOS-BUADES, Antoni (Nikhef)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **14** Type: **Talk**

Crystalline Silicon Blades- Suspension system for Einstein Telescope Project

Tuesday, 24 October 2023 11:00 (15 minutes)

The ET-LF test masses will be at cryogenic temperature. A new suspension idea was proposed to ensure good thermal conductivity, low mechanical stress, and low thermal noise. The idea is based on the use of flexural joints in compression. The disadvantage of this suspension is that vertical frequencies are high (16 Hz) and there are many possibilities that the 4 suspensions have a different load (different stress) value on the surface. Silicon is a high-quality factor material and ideally silicon vertical springs could provide low-thermal-noise attenuation, however the allowable tensional stress in crystalline springs result in vertical resonance frequency too high for attenuation. Reducing the vertical resonance frequency and/or to reduce the difference in stress between the suspensions.

Primary author: APPAVURAVTHER, ESRA ZERINA (Nikhef)

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **15** Type: **Talk**

Tidal properties of neutron stars in scalar-tensor theories of gravity

Tuesday, 24 October 2023 09:45 (15 minutes)

A major science goal of gravitational-wave (GW) observations is to probe the nature of gravity and constrain modifications to General Relativity. An established class of modified gravity theories are scalar-tensor models, which introduce an extra scalar degree of freedom. This affects the internal structure of neutron stars (NSs), as well as their dynamics and GWs in binary systems, where distinct novel features can arise from the appearance of scalar condensates in parts of the parameter space. To improve the robustness of the analyses of such GW events requires advances in modeling internal-structure-dependent phenomena in scalar-tensor theories. We develop an effective description of potentially scalarized NSs on large scales, where information about the interior is encoded in characteristic Love numbers or equivalently tidal deformabilities. We demonstrate that three independent tidal deformabilities are needed to characterize the configurations: a scalar, tensor, and a novel 'mixed' parameter, and develop the general methodology to compute these quantities. We also present case studies for different NS equations of state and scalar properties and provide the mapping between the deformabilities in different frames often used for calculations. Our results have direct applications for future GW tests of gravity and studies of potential degeneracies with other uncertain physics such as the equation of state or presence of dark matter in NS binary systems.

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Presenter: CRECI, Gastón (Utrecht University)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **17** Type: **Talk**

Hunting for gravitational waves in the era of cosmic dawn

Tuesday, 24 October 2023 14:30 (15 minutes)

Over the past decades, observations have established a sample of more than 200 bright Active galactic nuclei (AGN), powered by accretion onto massive black holes, in the first billion years of the Universe. The James Webb Space Telescope has significantly revised this sample by yielding a sample of unexpectedly numerous and large black holes (up to a 100 million solar masses) within the first 600 million years, posing an enormous challenge for black hole and galaxy formation models. Starting with possible pathways for creating such heavy black holes in the early Universe, I will show a census of the black holes and their properties expected through cosmic time. I will use these to highlight the gravitational wave event rates expected to be detected by LISA (the Laser Interferometer Space Antenna). Straddling the fields of cosmology, galaxy formation and black hole physics, I will show how theoretical models that couple the evolution of dark matter halos, their baryonic components and their black holes are crucially required to make predictions for facilities such as LISA.

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Presenter: DAYAL, Pratika (University of groningen)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **19** Type: **Talk**

Overview of LIGO-Virgo-Kagra data analysis and observational science

Monday, 23 October 2023 11:15 (25 minutes)

Original title: Comparing gravitational waveform models for binary black hole mergers: a hypermodels approach

The inference of source parameters from gravitational-wave signals relies on theoretical models that describe the emitted waveform. Different model assumptions on which the computation of these models is based could lead to biases in the analysis of gravitational-wave data. In this work, we sample directly on four state-of-the-art binary black hole waveform models from different families, in order to investigate these systematic biases from the 13 heaviest gravitational-wave sources with moderate to high signal-to-noise ratios in the third Gravitational-Wave Transient Catalog (GWTC-3). All models include spin-precession as well as higher-order modes. Using the "hypermodels" technique, we treat the waveform models as one of the sampled parameters, therefore directly getting the odds ratio of one waveform model over another from a single parameter estimation run.
From the joint odds ratio over all 13 sources, we find the model NRSur7dq4 to be favoured over SEOBNRv4PHM, with an odds ratio of 29.43; IMRPhenomXPHM and IMRPhenomTPHM have an odds ratio, respectively, of 4.70 and 5.09 over SEOBNRv4PHM. However, this result is mainly determined by three events that show a strong preference for some of the models and that are all affected by possible data quality issues. If we do not consider these potentially problematic events, the odds ratio do not exhibit a significant preference for any of the models. Although further work studying a larger set of signals will be needed for robust quantitative results, the presented method highlights one possible avenue for future waveform model development.

Primary author: PUECHER, Anna (Nikhef)

Presenter: PUECHER, Anna (Nikhef)

Session Classification: Instrumentation

Track Classification: Data Analysis

Contribution ID: **20** Type: **Talk**

Mirror coating test facility - cryogenic technology

Tuesday, 24 October 2023 09:15 (15 minutes)

The purpose of the cryogenic system of the mirror coating test facility is to keep the mirror samples at constant low temperature for optical measurements. Unlike the Einstein Telescope and Pathfinder, the system will not operate continuously. Discontinuous operation allows us to use a standard mechanical cryocooler along with energy storage. During measurements, the cryocooler is switched off to prevent coupling of vibrations. Stored energy is used to keep the mirror at the desired temperature. We will present an overview of the cryogenic system and indicate how we aim to optimize this system for measurements of roughly half an hour and a short regeneration time.

Primary author: LOTZE, Koen (University of Twente)

Co-author: Prof. TER BRAKE, Marcel (University of Twente)

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **21** Type: **Talk**

The Steady State Population of Intermediate-Mass Black Holes Near a Supermassive Black Hole

Tuesday, 24 October 2023 14:45 (15 minutes)

With the onset of next generation gravitational interferometers, we find ourselves in an era where we can peer into cosmic time and see the influence of mergers on the growth of supermassive black holes (SMBH). Here, we investigate properties of a cluster of intermediate-mass black holes surrounding a supermassive black hole. A model first proposed by Ebisuzaki et al. (2001) and for which Portegies Zwart et al. (2006) argue that such a population can exist in the core of the Milky Way.

We simulate clusters of equal-mass intermediate-mass black holes ($m_{\rm IMBH} = 10^3\ M_{sun}$) initialised in a shell between $0.15 \leq r$ [pc] ≤ 0.25 centred about a supermassive black hole. We explore the influence of the cluster population and supermassive black hole mass (exploring the values $M_{\rm SMBH} = 4\times10^5\ M_{sun,\ 4\times10^6\ M_{sun}}$ and $4\times10^7\ M_{sun}$) on the IMBH ejection rate and escape velocity.

For $M_{\rm SMBH} = 4\times10^6\ M_{sun}$, we use both a Newtonian and post-Newtonian formalism, going up to the 2.5th order, including cross-terms. We run 40 and 60 simulations per cluster population for either formalism respectively. For the other two SMBH-mass configurations, we model the system taking into account relativistic effects. In the case of $M_{\rm SMBH} = 4\times10^5\ M_\odot$, 30 simulations are run per population. For $M_{\rm SMBH} = 4\times10^7\ M_\odot$ we run 10 simulations per population. The simulations end once a black hole escapes the cluster, a merger occurs, or the system has evolved till 100 Myr.

We find that clusters evolved with the post-Newtonian formalism lose their intermediate-mass black holes quicker than those evolved under Newtonian gravity. Lowest-mass SMBHs predominantly experience ejections. Increasing the supermassive black holes causes the merger rate to increase. Although relativistic effects allow for lower eccentricity mergers, all merging binaries have e
$gtrsim 0.97$ when measured $1-2$ kyr before the merging event.

Most of the strongest gravitational wave signals originate from merging IMBHs that form a binary with the SMBH and eventually merge. Weaker and more frequent signals are expected from gravitational wave radiation emitted in a fly-by.

Both processes are suppressed in the non-relativistic calculations. In these simulations, the IMBHs tend to stall in the vicinity of the SMBH, after which they usually eject via the sling shot mechanism. For all configurations, no IMBH-IMBH binaries were detected.

In our post-Newtonian calculations, when it comes to SMBH-IMBH binary systems emitting strong gravitational wave signals, 11.4% of them are detected as gravitational wave capture binaries, while the remaining 86.6% are in-cluster merging binaries.

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Presenter: HOCHART, Erwan (Leiden Observatory)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **22** Type: **Talk**

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

Tuesday, 24 October 2023 10:00 (15 minutes)

Future detections of gravitational waves originating from binary neutron star mergers or core-collapse supernovae offer the potential to gain unprecedented insights into the structure of matter at densities far beyond those probed by Earth-based experiments. In order to be able to identify the correct equation of state of matter, a template bank of waveforms has to be generated by general relativistic magnetohydrodynamics simulations. However, state-of-the-art solvers are slowed down by the conservative-to-primitive transformation, a central algorithmic step in any relativistic hydrodynamics solver. We investigate the potential of three machine learning algorithms to improve existing conservative-to-primitive schemes. We find that fully replacing either the conservative-to-primitive transformation or the evaluation of the equation of state by a machine learning model is unable to provide any significant advantage. We propose a novel, hybrid scheme that unifies machine learning and state-of-the-art schemes, resulting in an acceleration of numerical solvers by up to 25% for general relativistic magnetohydrodynamics simulations involving microphysical equations of state, without compromising accuracy or robustness.

Primary author: WOUTERS, Thibeau (Utrecht University)

Presenter: WOUTERS, Thibeau (Utrecht University)

Session Classification: Astrophysics & Cosmology

Track Classification: Data Analysis

Contribution ID: **23** Type: **Talk**

Generating template banks for searches of precessing Binary Black Holes

Tuesday, 24 October 2023 09:45 (15 minutes)

We introduce a novel method to generate a bank of gravitational-waveform templates of binary Black Hole (BBH) coalescences for matched-filter searches in LIGO, Virgo and Kagra data.
Unlike the standard approach, our method relies on a numerical metric approximation of the match between templates, for which we derive an expression suitable to precessing waveforms. We use the determinant of the metric to define a probability measure at any point of the parameter space and, to make the sampling and density evaluation feasible, we train a normalizing flow model targeting the probability distribution on the parameter space. Based on the samples of the normalizing flow model, we devise several strategies to place the templates for a new template bank.
Our method applies to a variety of different manifolds of signals and is particularly suitable for covering high-dimensional spaces, such as those associated with precessing and/or eccentric waveforms.
To demonstrate the capabilities of our code, we generate a bank for precessing black holes and show that it covers the space in a satisfactory way. Our publicly released code mbank will enable searches of high-dimensional regions of BBH signal space, hitherto unfeasible due to the prohibitive cost of bank generation.

Primary authors: GADRE, Bhooshan; CAUDILL, Sarah; SCHMIDT, Stefano

Presenter: SCHMIDT, Stefano

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **24** Type: **Talk**

Updates from the Omnisens project, a 6D sensor and active platform for low frequency seismic isolation

Tuesday, 24 October 2023 11:15 (15 minutes)

We want the future Einstein Telescope gravitational wave detector to be sensitive from 3Hz onwards. To reach this low frequency sensitivity we need to break the low frequency seismic wall and battle the controls noise that is limiting current detectors at 20Hz.
At Nikhef and the Vrije Universiteit Amsterdam, the Omnisens project is building a prototype of an active platform with a 6D sensor to improve seismic isolation at low frequencies.
This talk will explain how the 6D system works, update with the progress of our prototype, and share the implications of our simulation models for the Einstein Telescope.

Primary author: DONGEN, Jesse van

Co-authors: MITCHELL, Alexandra; MOW-LOWRY, Conor; VALENTINI, Michele; HOLLAND, Nathan; SAFFARIEH, Pooya

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **25** Type: **Talk**

Estimating Astrophysical Population Properties using a multi-component Stochastic Gravitational-Wave Background Search

Tuesday, 24 October 2023 10:00 (15 minutes)

The recent start of the fourth observing run of the LIGO-Virgo-KAGRA (LVK) collaboration has reopened the hunt for gravitational-wave (GW) signals, with one compact-binary-coalescence (CBC) signal expected to be observed every few days. Among the signals that could be detected for the first time there is the stochastic gravitational-wave background (SGWB) from the superposition of unresolvable GW signals that cannot be detected individually. In fact, multiple SGWBs are likely to arise given the variety of sources, making it crucial to identify the dominant components and assess their origin. However, current search methods with ground-based detectors assume the presence of one SGWB component at a time, which could lead to biased results in estimating its spectral shape if multiple SGWBs exist. Therefore, a joint estimate of the components is necessary. In this work, we adapt such an approach and analyse the data from the first three LVK observing runs, searching for a multi-component isotropic SGWB. We do not find evidence for any SGWB and establish upper limits on the dimensionless energy parameter $\Omega_{\rm gw}(f)$ at 25 Hz for five different power-law spectral indices, $\alpha = 0,\, 2/3,\, 2,\, 3,\, 4$, jointly. For the spectral indices $\alpha = 2/3,\, 2,\, 4$, corresponding to astrophysical SGWBs from CBCs, r-mode instabilities in young rotating neutron stars, and magnetars, we draw further astrophysical implications by constraining the ensemble parameters $K_{\rm CBC},\, K_{\rm r-modes},\, K_{\rm magnetars}$, defined in the main text.

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Presenter: DE LILLO, Federico (UCLouvain - CP3)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **26** Type: **Talk**

Combining individual binary black hole detections and gravitational-wave background data to infer the binary black hole time-delay distribution

Monday, 23 October 2023 17:00 (15 minutes)

The advent of gravitational-wave astronomy is now allowing for the study of compact binary merger demographics throughout the Universe. This information can be leveraged as tools for understanding massive stars, their environments, and their evolution. One active question is the nature of compact binary formation: the environmental and chemical conditions required for black hole birth and the time delays experienced by binaries before they merge. Gravitational-wave events detected today, however, primarily occur at low or moderate redshifts due to current interferometer sensitivity, therefore limiting our ability to probe the high redshift behavior of these quantities. We circumvent this limitation by using an additional source of information: observational limits on the gravitational-wave background from unresolved binaries in the distant Universe. Using current gravitational-wave data from the first three observing runs of LIGO-Virgo-KAGRA, we synthesize catalogs of directly detected binaries and limits on the stochastic background to constrain the time-delay distribution and metallicity dependence of binary black hole evolution. Looking to the future, we also explore how these constraints will be improved at the Advanced LIGO A+ sensitivity.

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Presenter: TURBANG, Kevin (Vrije Universiteit Brussel/Universiteit Antwerpen)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **27** Type: **Talk**

Towards Precision Cosmology with Galaxy Catalogues

Tuesday, 24 October 2023 11:15 (15 minutes)

The increasing number of GW detections paves the road towards pinning down the values of the most important cosmological parameters, enabling us to do precision cosmology. This approach requires the careful mitigation of various systematic effects, which become more and more important as the accuracy of our cosmological inference grows. In this talk, I will present the UpGLADE galaxy catalogue, which is the most comprehensive tool for aiding GW cosmology from the electromagnetic side.

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Presenter: DÁLYA, Gergely (Ghent University)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **28** Type: **Talk**

’Black hole ringdown modelling: linking the horizon dynamics to the gravitational wave observations’

Monday, 23 October 2023 16:45 (15 minutes)

The last phase of a black hole merger is accompanied by a train of damped gravitational radiation known as the ringdown. It can be described linearly at late times, as a sum of discrete modes: the quasi-normal modes (QNMs) of the final Kerr black hole. As a consequence of the black hole no-hair theorem, the QNM frequencies are fully determined by the mass and spin of this black hole. Measures of these frequencies then enable tests of this prediction of GR e.g. by comparison between multiple QNMs. It has been suggested that ringdown signals may be modelled by QNMs already from the merger onwards using a large enough number of modes (overtones), which could remove the need to analyse much quieter late-time signals. I will present and discuss the results of further tests of this claim from numerical relativity results in two regimes: the local dynamics of the final horizon, and the closely related gravitational radiation itself when modelled with many QNM overtones. I will in particular discuss the stability of the recovery of individual QNM tones and the resulting prospects for spectroscopic tests of GR; as well as comparisons to a few phenomenological models beyond the linear QNMs.

Primary author: JIMENEZ FORTEZA, Xisco (Utrecht University and Nikhef)

Presenter: JIMENEZ FORTEZA, Xisco (Utrecht University and Nikhef)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **29** Type: **Talk**

Gravitational lensing of standard sirens: a systematic effect on cosmological parameters' estimation.

Tuesday, 24 October 2023 12:00 (15 minutes)

Since the first detection, Gravitational Waves (GWs) have opened a new observational window on our Universe. When accompanied by an electromagnetic detection, GWs emitted by merging binaries of compact objects can be used as "standard sirens" to probe the distance-redshift relation and the standard model of cosmology. However, as in the case of light, we expect GW signals to be bent during their trajectory towards our detectors by the intervening matter field, a well-known phenomenon called gravitational lensing. This induces modifications on the measurement of the luminosity distance compared to that of a homogeneous universe. In this talk, I will present how lensing can impact the power of standard sirens for cosmological studies. The scenario is that of third-generation ground-based GW detectors, which are expected to achieve impressive measurement accuracies that will open the era of precision GW cosmology. Treating lensing as a systematic error, I will point out that it can induce a bias in the estimation of the cosmological parameters and quantify the bias in relation to the characteristics of a catalog of future GW events. For our fiducial scenario, I will show evidence that lensing bias can be comparable to or greater than the forecasted statistical uncertainty of the cosmological parameters, although non-negligible fluctuations in the bias values are observed for different realisations of the mock catalog. I will conclude by discussing some mitigation strategies that can be adopted in the data analysis.

Primary author: CANEVAROLO, Sofia

Co-author: CHISARI, Elisa (Utrecht University)

Presenter: CANEVAROLO, Sofia

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **30** Type: **Poster**

Two-coloured laser light to control the Einstein Telescope

Tuesday, 24 October 2023 13:30 (5 minutes)

The Einstein Telescope uses laser light to precisely monitor the distance between two freely hanging mirrors placed several kilometres apart, to search for traces of gravitational waves that are passing by. The mirrors are made from large silicon crystals and require a specific laser colour for best sensitivity. This research shows how combining this laser light with another laser colour can control the mirrors to an extremely stable position, letting the Einstein Telescope listen to the faintest waves

Primary authors: STEINLECHNER, Sebastian (Maastricht University & Nikhef); SCHOON, Tobias; GUO, Yuefan

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **31** Type: **Talk**

Stochastic gravitational wave background constraints from Gaia DR3 astrometry

Tuesday, 24 October 2023 10:15 (15 minutes)

Astrometric surveys can be used to constrain the stochastic gravitational wave background (SGWB) at very low frequencies. The European Space Agency's (ESA) Gaia mission, launched in 2013 and with a recent data release (DR3) in 2022, shows great potential for this purpose. In this talk, I will present a recent work in which we used Gaia DR3 to set constraints on the SGWB amplitude. I will also comment on previous works which computed similar constraints and discuss the potential of future Gaia data releases to impose tighter bounds.

Primary author: JARABA, Santiago (Instituto de Física Teórica (UAM-CSIC))

Presenter: JARABA, Santiago (Instituto de Física Teórica (UAM-CSIC))

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **32** Type: **Talk**

The Eyes of LISA

Tuesday, 24 October 2023 09:00 (15 minutes)

The Dutch contribution to the Laser Interferometer Space Antenna (LISA) covers both hardware and data analysis. Focusing on the hardware, the Netherlands will deliver 'The Eyes of LISA', known as the Quadrant Photo-Receivers (QPRs), made up of segmented InGaAs photodiodes with read-out electronics in an ultra-stable housing. Furthermore, The Netherlands is developing the Point Ahead Alignment Mechanism (PAAM), consisting of a nanorad-accurate steerable mirror pointing the outgoing laser beam to meet the advancing opposite spacaecraft during the light travel time. In addition, The Netherlands will provide the Mechanism Control Unit, i.e. special electronics to readout and control the PAAM as well as host electronics for other adaptable optics in LISA. The QPR is a joint development program by Nikhef and SRON, Dutch industry, KU Leuven and the Albert Einstein Institute in Hannover. This talk will focus on the challenges on delivering 120 QPR systems for flight, spares and tests, that meet the requirements that are demanded by the mission.

Primary author: MISTRY, Timesh (Nikhef)

Co-authors: Dr IN 'T ZAND, Jean (SRON); Mr ADAMS, Martin (Nikhef); Dr SIEGL, Martin (TNO); Dr VAN BEUZEKOM, Martin (Nikhef); Dr VAN BAKEL, Niels (Nikhef); Mr CORNELISSEN, Robin (Nikhef)

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **33** Type: **Talk**

Joint parameter estimation on overlapping gravitational wave signals from coalescing compact binaries with Einstein Telescope and Cosmic Explorer

Monday, 23 October 2023 16:15 (15 minutes)

Current parameter-estimation techniques for the coalescence of compact binaries assume just one event in the data stream. With the low detection rate of current interferometers, is has not been a problem so far, as overlapping signals are highly improbable. This will change with the next generation (3G) of detectors, like Cosmic Explorer and Einstein Telescope, with hundreds of overlaps per year. Previous work has shown that not accounting for them can lead to biases in the parameter estimation.

In our work we tackle this problem by performing joint parameter estimation – modeling multiple sources in the data at once. Previously, this technique was too computationally expensive to use with long-duration signals expected in 3G detectors, but we have combined it with a likelihood approximation known as relative binning, making the analysis feasible. For comparison, we also perform hierarchical subtraction, where we model one signal at a time, subtract it from data and analyze again.

We consider overlapping signal scenarios of two binary black hole signals and two neutron star signals. Using the joint parameter estimation we are able to accurately estimate the parameters, mitigating the bias observed when we model just one signal at a time.

Primary author: BAKA, Tomek (Utrecht University, Nikhef)

Co-authors: SAMAJDAR, Anuradha; VAN DEN BROECK, Chris; JIMENEZ FORTEZA, Francisco; JANQUART, Justin; DIETRICH, Tim

Presenter: BAKA, Tomek (Utrecht University, Nikhef)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **34** Type: **Talk**

Research & Development of novel position sensors and actuators for seismic attenuation systems of ETpathfinder

Tuesday, 24 October 2023 10:00 (15 minutes)

The precise monitoring and active damping of seismic noise are paramount in gravitational wave (GW) detectors. This presentation outlines our research focused on the application of Linear Variable Differential Transformers (LVDTs) as position sensors in these detectors. LVDTs, based on mutual induction, offer a non-contact, linear response.

A simulation framework has been developed using pyFEMM, a Python extension for finite element method magnetics, to model and simulate various LVDT designs.
Initial coil production for ETpathfinder has been setup including the creation of a comprehensive checklist for machine settings and procedures. Comprehensive tests have been conducted to evaluate coil performance, including sensitivity, impedance, force measurements, and noise analysis. These tests provide insights into the efficiency of produced LVDTs, including their linear and non-linear movement ranges and response characteristics.

Primary author: KUKKADAPU, Kumar Akhil (University of Antwerp)

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **35** Type: **Talk**

Detection of anomalies amongst LIGO's glitch populations with autoencoders

Tuesday, 24 October 2023 09:30 (15 minutes)

Non-Gaussian, transient bursts of noise in gravitational wave (GW) interferometers, also known as glitches, hinder the detection and parameter estimation of short- and long-lived GW signals in the main detector strain. Glitches come in a wide range of frequency-amplitude-time morphologies and may be caused by environmental or instrumental processes, so a key step towards their mitigation is to understand their population. Current approaches for their identification use supervised models to learn their morphology in the main strain with a fixed set of classes, but do not consider relevant information provided by auxiliary channels that monitor the state of the interferometers. In this work, we present an unsupervised algorithm to find anomalous glitches. Firstly, we encode a subset of auxiliary channels from LIGO Livingston in the fractal dimension, which measures the complexity of the signal. For this aim, we speed up the fractal dimension calculation to near-real time. Secondly, we learn the underlying distribution of the data using an autoencoder with cyclic periodic convolutions. In this way, we learn the underlying distribution of glitches, and we uncover unknown glitch morphologies and overlaps in time between different glitches and misclassifications. This led to the discovery of 6.6% anomalies in the input data. The results of this investigation stress the learnable structure of auxiliary channels encoded in the fractal dimension and provide a flexible framework for glitch discovery.

Primary author: LOPEZ, Melissa

Co-authors: CAUDILL, Sarah; SCHMIDT, Stefano; MILLER, Andrew; BROECK, Chris Van Den; DRIESSENS, Kurt (DKE, Maastricht University)

Presenter: LOPEZ, Melissa

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **36** Type: **Talk**

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

Tuesday, 24 October 2023 09:00 (15 minutes)

Once a gravitational wave signal is detected, the measurement of its source parameters is important to achieve various scientific goals. This is done through Bayesian inference, where the analysis cost increases with the model complexity and the signal duration. For typical binary black hole signals with precession and higher-order modes, one has 15 model parameters. With standard methods, such analyses require at least a few days. For strong gravitational wave lensing, where multiple images of the same signal are produced, the joint analysis of two data streams requires 19 parameters, further increasing the complexity and run time. Moreover, for third generation detectors, due to the lowered minimum sensitive frequency, the signal duration increases, leading to even longer analysis times. With the increased detection rate, such analyses can then become intractable. In this work, we present a fast and precise parameter estimation method relying on relative binning and capable of including higher-order modes and precession. We also extend the method to perform joint Bayesian inference for lensed gravitational wave signals. Then, we compare its accuracy and speed to those of state-of-the-art parameter estimation routines by analyzing a set of simulated signals for the current and third generation of interferometers. Additionally, for the first time, we analyze some real events known to contain higher-order modes with relative binning. For binary black hole systems with a total mass larger than $50M_{\odot}$, our method is about 2.5 times faster than current techniques. This speed-up increases for lower masses, with the analysis time being reduced by a factor of 10 on average. In all cases, the recovered posterior probability distributions for the parameters match those found with traditional techniques.

Primary author: NAROLA, Harsh (Utrecht University)

Co-authors: VAN DEN BROECK, Chris; MALIYAMVEETTIL, Haris; JANQUART, Justin; MEIJER, Quirijn (Utrecht University)

Presenter: NAROLA, Harsh (Utrecht University)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **37** Type: **Talk**

Evaluating the GW detectability of stellar populations using BPASS and LEGWORK

Monday, 23 October 2023 14:45 (15 minutes)

Using BPASS, we have created population synthesis models for several types of stellar populations, including open clusters, globular clusters and the LMC. We focus particularly on the binaries in these populations that generate GWs which may be detectable by LISA, and we evaluate the detectability using LEGWORK. We find that MW globular clusters typically contain a few binaries in the LISA frequency range, but only a small fraction of these would be detectable. Our overall numbers are lower than those of other predictions of GWs from globular clusters, which we attribute to the BPASS models not including dynamical interactions that would occur in dense clusters. Finally, we discuss our proposed method of including these dynamical effects in our simulations.

Primary author: VAN ZEIST, Wouter

Presenter: VAN ZEIST, Wouter

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **38** Type: **Poster**

Optical prototyping at VUB Brussels Photonics (B-PHOT)

Tuesday, 24 October 2023 13:35 (5 minutes)

In this poster we present optics prototyping procedures, including sillicon optics, that are relevant to production, metrology and assembly of components for ET Pf and future full scale GW interferometers. We present several case studies and illustrate benefits of our procedures and integrated in-house production process.

Primary authors: TOPIC, Sasa (Vrije Universitet Brussels B-PHOT); Dr THIENPONT, Hugo (VUB); Dr VERVAEKE, Michael (VUB B-PHOT)

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **39** Type: **Talk**

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

Tuesday, 24 October 2023 11:30 (15 minutes)

In this talk we present a comprehensive software overview that is necessary for simulation, design and fabrication of high tolerance cavities in 3G GW Interferometers. An in-depth review of software is given along with the prescribed workflows and production/metrology loops. We discuss the complementary of different software solutions and aplications of FFT, modal and ABCD(EF) matrix approaches and position the relevant software products in the overall ecosystem for simulations and design of aforementioned cavities.

Primary authors: TOPIC, Sasa (Vrije Universitet Brussels B-PHOT); SORGATO, Simone (VUB, Brussels Photonics B-Phot); Prof. THIENPONT, Hugo (Vrije Universitet Brussels B-PHOT); PASCUCCI, Daniela (Ghent University); SCHOON, Tobias; Dr VERVAEKE, Michael (Vrije Universitet Brussels B-PHOT)

Session Classification: Instrumentation

Track Classification: Instrumentation and R&D

Contribution ID: **40** Type: **Poster**

Semianalytic code for I/O mode cleaners design

Tuesday, 24 October 2023 13:35 (5 minutes)

In this poster I will present semi-analytic code designed to simulate modal propagation and coupling of Hermite-Gauss laser modes in and out of the Input and Output mode cleaner cavities that will be used on R&D and 3G detectors. Outputs from the code are graphical plots that serve as heuristic tools for narrowing down choices of cavity parameters (RoC, L, Finesse, internal angles etc.). The code is based on a modal decomposition of HG modes and expansion procedure, that is valid up to second order, for HG beams and as varying parameters has Finesse of cavity, internal angles and cavity geometry, mode mismatch, misalignment etc. Short overview of ideas behind the code will be presented along with some graphical results and their interpretation.

Primary authors: TOPIC, Sasa (Vrije Universitet Brussels B-PHOT); THIENPONT, Hugo (VUB); VERVAEKE, Michael (VUB B-PHOT)

Presenter: TOPIC, Sasa (Vrije Universitet Brussels B-PHOT)

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **41** Type: **Talk**

Clustering of gravitational waves in LCDM and effective field theories of gravity

Tuesday, 24 October 2023 12:15 (15 minutes)

In the era of large scale galaxy surveys, significant effort has been put in constraining cosmological models with unprecedented precision. In this context, gravitational waves (GW) might play a pivotal role to improve our understanding of the Universe. In particular, the clustering of gravitational waves potentially allows to constrain perturbation growth, similarly to galaxy clustering. As is the case for galaxies, the clustering of GW that can be measured from observations suffers from a number of relativistic corrections that affect the measured signal. In my talk, I will discuss the relativistic effects affecting GW clustering, and the detectability of the total signal by current and planned GW detectors. I will also discuss how this clustering can be used in synergy with other cosmological probes to constrain cosmologies.

Primary author: BALAUDO, Anna (Leiden University)

Co-authors: SILVESTRI, Alessandra (Leiden University); PANTIRI, Mattia (Leiden University)

Presenter: BALAUDO, Anna (Leiden University)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **42** Type: **Talk**

Luminosity of the darkness

Tuesday, 24 October 2023 11:30 (15 minutes)

Dark siren measurement of Hubble constant is one of the most exciting results in the multimessenger astronomy. Currently, the uncertainty of this measurement is dominated by the unknown gravitational wave events population. However with more events and better sensitivity of detectors, the uncertainty will shrink, therefore it is important to study impact of uncertainties from different sources, especially from electromagnetic side of the measurement. In my talk I will focus on the unknown distribution of luminosity of galaxies that are out of reach of our telescopes - the luminosity of the darkness. I will focus on its impact on galaxy distributions and on Hubble constant measurement.

Primary author: TURSKI, Cezary (Ghent University)

Presenter: TURSKI, Cezary (Ghent University)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **43** Type: **Talk**

Ringdown of rotating black holes in higher-derivative gravity

Tuesday, 24 October 2023 09:30 (15 minutes)

We computed the spectrum of linearized gravitational excitations of black holes with substantial angular momentum in the presence of higher-derivative corrections to general relativity. We do so perturbatively to leading order in the higher-derivative couplings and to more than twelve orders in the black hole angular momentum. This allows us to accurately predict quasi-normal mode frequencies of black holes with spins up to about 0.7 of the extremal value. For some higher-derivative corrections, we find that sizeable rotation will enhance the frequency shifts relative to the static case. (Presentation based on 2304.02663 and 2307.07431.)

Primary author: MAENAUT, Simon (KU Leuven)

Presenter: MAENAUT, Simon (KU Leuven)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **44** Type: **Poster**

The impact of the magnetic correlated noise on the anisotropic stochastic gravitational wave background

Tuesday, 24 October 2023 13:40 (15 minutes)

One potential factor that could impede searches for the stochastic gravitational-wave background (SGWB) — arising from the incoherent superposition of numerous unresolvable signals in the universe — is correlated noise at Earth-scale distances, such as the Schumann resonances. With the dawn of next-generation detectors, these effects are expected to become even more pronounced, emphasizing the importance of considering correlated noise sources in SGWB searches. In this study, we delve into the influence of such noises on anisotropic SGWB searches. To this end, we carried out an all-sky, all-frequency stochastic directional search using data from the LEMI-120 (Advanced LIGO) and the Metronix MFS-06e (Advanced Virgo) magnetometers. We then compared these measurements with the directional upper limit derived from gravitational-wave data collected during the first three observing runs of the LIGO-Virgo-KAGRA collaboration. Our preliminary results indicate that the magnetic correlations are subleading compared with the anisotropic SGWB with the current detector sensitivity.

Primary author: VENIKOUDIS, Stavros (UCLouvain - CP3)

Co-authors: DE LILLO, Federico (UCLouvain - CP3); BRUNO, Giacomo (University of Louvain (UCLouvain), Belgium); SURESH, Jishnu (UCLouvain - CP3); Dr JANSSENS, Kamiel (Universiteit Antwerpen)

Session Classification: Posters

Track Classification: Data Analysis

Contribution ID: **45** Type: **Talk**

Sequential simulation-based inference for gravitational waves of the current and future era

Tuesday, 24 October 2023 09:15 (15 minutes)

The current and upcoming generations of gravitational wave experiments represent an exciting step forward in terms of detector sensitivity and performance. Key upgrades at the LIGO, Virgo and KAGRA facilities will see the next observing run (O4) probe a spatial volume around four times larger than the previous run (O3), and design implementations for e.g. the Einstein Telescope, Cosmic Explorer and LISA experiments are taking shape to explore a wider frequency range and probe cosmic distances.

In this context, however, a number of imminent data analysis problems face the gravitational wave community. It will be crucial to develop tools and strategies to analyze (amongst other scenarios) signals that arrive coincidentally in detectors, longer signals that are in the presence of non-stationary noise or other shorter transients, as well as noisy, potentially correlated, coherent stochastic backgrounds. With these challenges in mind, we develop *PEREGRINE*, a new sequential simulation-based inference approach designed to study broad classes of gravitational wave signal.

In this talk, I discuss the need of the hour for flexible, simulation-efficient, targeted inference tools like *PEREGRINE* before demonstrating its accuracy and robustness through direct comparison with established likelihood-based methods. Specifically, we show that we are able to fully reconstruct the posterior distributions for every parameter of a spinning, precessing compact binary coalescence using one of the most physically detailed and computationally expensive waveform approximants (SEOBNRv4PHM). Crucially, we are able to do this using only 2% of the waveform evaluations that are required in e.g. nested sampling approaches, highlighting our simulation efficiency as the state-of-the-art when it comes to gravitational waves data analysis.

Primary author: Mr BHARDWAJ, Uddipta (GRAPPA, University of Amsterdam)

Presenter: Mr BHARDWAJ, Uddipta (GRAPPA, University of Amsterdam)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **46** Type: **Poster**

Optimal control for seismic isolation platforms

Tuesday, 24 October 2023 13:40 (5 minutes)

In gravitational detectors, the presence of numerous subsystems, each governed by distinct control loops with numerous parameters, presents a complex optimization challenge. This poster addresses the optimization problem by employing H-infinity (H-inf) and H-2 control techniques to enhance the performance of these subsystems. Our goal is to optimize a cost function that reflects an overall macroscopic figure of merit which is more physically motivated compared to optimization of each subsystem.

Primary author: SAFFARIEH, Pooya

Co-authors: MITCHELL, Alexandra; MOW-LOWRY, Conor; DONGEN, Jesse van; VALENTINI, Michele; HOLLAND, Nathan

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **47** Type: **Talk**

Angular power spectra of anisotropic stochastic gravitational wave background: Developing statistical methods and analyzing data from ground-based detectors

Tuesday, 24 October 2023 15:15 (15 minutes)

Unresolved sources of gravitational waves can create a stochastic gravitational wave background (SGWB) which may have intrinsic or extrinsic anisotropies. The angular power spectrum is a well-suited estimator for characterizing diffuse anisotropic distributions in the sky. Here we estimate the first model-independent all-sky all-frequency SGWB angular power spectra in the 20-1726 Hz frequency range from the third observing run (O3) of the Advanced LIGO and Advanced Virgo detectors. We develop a method to use the spectrum's signal-to-noise ratio as the detection statistic and show that the shape of the distribution of the statistic obtained from the data agrees with the analytical model with a modified value of the parameter. Since we find the data to be consistent with noise, 95% confidence Bayesian upper limits are set on the angular power spectra, ranging from $C_\ell^{1/2} \leq (3.0 \times 10^{-9} - 0.73)$ sr^{-1}. We also introduce a method to combine the narrow band angular power spectra to obtain estimators for broadband SGWB. These results can directly constrain theoretical models that predict the SGWB angular power spectra and for estimating or constraining the corresponding parameters. In addition, the results and the techniques introduced in this work can be useful for performing correlation-based searches, for instance, with electromagnetic observations.

Primary author: AGARWAL, Deepali

Co-authors: SURESH, Jishnu (UCLouvain - CP3); Prof. MITRA, Sanjit (IUCAA); Dr AIN, Anirban

Presenter: AGARWAL, Deepali

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **49** Type: **Talk**

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

Tuesday, 24 October 2023 11:00 (15 minutes)

Currently, calibration errors in gravitational wave detectors are often modelled through an amplitude scaling and time jittering. While this is a valid approximation for narrowband signals, it might not be sufficient for broadband signals such as core-collapse supernovae (CCSNe). In this work, we present a plugin for coherent WaveBurst that uses the most accurate estimates of calibration uncertainty in the LIGO detectors. The effect of these calibration errors is demonstrated on the O3 targeted CCSN search.

Primary author: WILS, Milan (KU Leuven)

Presenter: WILS, Milan (KU Leuven)

Session Classification: Astrophysics & Cosmology

Track Classification: Data Analysis

Contribution ID: **50** Type: **Talk**

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

Tuesday, 24 October 2023 10:15 (15 minutes)

Modelling the gravitational-wave (GW) emission of core-collapse supernovae is needed to, e.g., relate a detected GW to the properties of its source or test different models. To obtain such models, we will use the GRMHD code *Gmunu* to study the effect of different parameters of the collapsing star on the waveforms.

Primary author: OFFERMANS, Arthur

Presenter: OFFERMANS, Arthur

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **51** Type: **Talk**

Simulation-based inference for stochastic gravitational wave background data analysis

Monday, 23 October 2023 17:15 (15 minutes)

The next generation of space- and ground-based facilities promise to reveal an entirely new picture of the gravitational wave sky: thousands of galactic and extragalactic binary signals, as well as stochastic gravitational wave backgrounds (SGWBs) of unresolved astrophysical and possibly cosmological signals. Here, I will focus on one particular analysis challenge: reconstructing an SGWB from mock LISA data. I demonstrate that simulation-based inference (SBI) is a promising avenue to overcome some of the technical difficulties and compromises necessary when applying more traditional methods like MCMC. As a demonstration of the rich potential of SBI, I consider the injection of a population of low signal-to-noise ratio supermassive black hole transient signals into the data, which SBI automatically marginalises over. I will close with an outlook on the general potential of SBI for gravitational wave science.

Primary authors: Dr WENIGER, Christoph (University of Amsterdam); ALVEY, James (University of Amsterdam); Dr PIERONI, Mauro (CERN); Mr BHARDWAJ, Uddipta (GRAPPA, University of Amsterdam); Dr DOMCKE, Valerie (CERN)

Presenter: Dr WENIGER, Christoph (University of Amsterdam)

Session Classification: Data Analysis

Track Classification: Data Analysis

Contribution ID: **52** Type: **Poster**

Cosmological inference using the Line Of Sight Redshift Prior

Tuesday, 24 October 2023 15:00 (15 minutes)

GWcosmo is a package to estimate cosmological parameters using gravitational-wave observations with galaxy catalogues. Its current version for LVK Run O4 makes use of a precomputed 'Line Of Sight Redshift Prior', which encodes the redshift information of the galaxies and improves the computing time of the analysis.

Primary author: BEIRNAERT, Freija (Ghent University)

Presenter: BEIRNAERT, Freija (Ghent University)

Session Classification: Astrophysics & Cosmology

Track Classification: Astrophysics & Cosmology

Contribution ID: **53** Type: **not specified**

Discussion: Future BE-NL Meetings

Monday, 23 October 2023 13:30 (30 minutes)

Contribution ID: **57** Type: **not specified**

Emerging evicende for nano-Hertz gravitational wave signals in Pulsar Timing Array data: history, recent results and future prospects

Monday, 23 October 2023 09:40 (50 minutes)

Presenter: JANSSEN, Gemma (Astron)

Contribution ID: **58** Type: **Talk**

Status of the Einstein Telescope

Monday, 23 October 2023 11:40 (25 minutes)

Presenter: FREISE, Andreas

Session Classification: Instrumentation

Contribution ID: **59** Type: **not specified**

Short interview Ed van den Heuvel on early days of GW Astronomy

Monday, 23 October 2023 14:00 (15 minutes)

Session Classification: Astrophysics & Cosmology

Contribution ID: **60** Type: **not specified**

GW afterglow searches with MeerKAT, VLA and EVN radio telescopes

Monday, 23 October 2023 15:00 (15 minutes)

Presenter: VAN LEEUWEN, Joeri

Session Classification: Astrophysics & Cosmology

Contribution ID: **61** Type: **not specified**

Parralel session summary (Instrumentation)

Session Classification: Astrophysics & Cosmology

Contribution ID: **62** Type: **Poster**

High-Quality Coating Materials for future Cryogenic Gravitational-Wave Advanced Detectors

Tuesday, 24 October 2023 13:45 (20 minutes)

Interferometric gravitational-wave detectors have opened a new window into the Universe, creating new opportunities in the branch of astrophysics. While current detectors allow for successful detections, there is a need to increase their sensitivity by trying to enlarge their frequency band to observe additional types of gravitational waves sources. Future cryogenic detectors such as the Einstein Telescope aim for this improvement. Improved operating conditions, such as cryogenic temperature, will help reduce the mirror's Brownian thermal noise, one of the limiting noises in the detector. Meanwhile, low temperature applications are driving technological development towards the study of new materials and coating design for the mirrors of these large interferometers. Material candidates such as amorphous silicon (aSi) and silicon nitrides (SiN) show low thermal noise but their high optical absorption reduces the power in the interferometer and hence the signal-to-noise ratio. In Maastricht University, we are testing a crystalline-silicon top-layer design, based on the industrially established silicon-on-insulator (SOI) technique, which will allow the use of low thermal-noise but highly-absorbing materials such as aSi and SiN. In addition, this new design will potentially reduce the defect density in the upper coating layers, where the high laser power may induce damages, and solve a mismatch in tolerable heat-treatment temperatures of the coating and the mirror substrate.

Presenter: AMATO, Alex (Maastricht University)

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **63** Type: **Poster**

Mirror Coatings for Gravitational-Wave Detectors

Tuesday, 24 October 2023 13:40 (20 minutes)

Highly-reflective coated mirrors are the heart of interferometric gravitational-wave detectors, such as LIGO, Virgo and the planned Einstein Telescope. However, thermal noise of the coatings is one of the limiting noise sources of the detectors, preventing us from seeing weaker, more distant or new astrophysical objects. Besides reduced thermal noise, there are also a number of strict requirements on the optical properties of such coatings, making it extremely challenging to achieve significant improvements.
This poster will explain the role of mirror coatings in gravitational-wave detectors and the requirements and challenges in developing new coatings for current and future detectors. The aim of this poster is to give an overview of this complex research topic, tackled by several dozens of research groups world wide, to provide the fundamentals and context of the more specific research topics currently targeted within the Netherlands and presented on related posters.

Presenter: STEINLECHNER, Jessica

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **64** Type: **not specified**

New coating materials for thermal noise reduction in room temperature gravitational wave detectors

Tuesday, 24 October 2023 13:40 (20 minutes)

New challenges in gravitational-wave astrophysics impose increasing sensitivity of current interferometric detectors operating at room temperature as Advanced LIGO and Advanced Virgo. Limits at their most sensitive frequency region arise from the Brownian thermal noise of the highly-reflective coatings on the interferometer mirrors. Such coatings are composed of alternating layers of low- and high-refractive index materials.
For upcoming upgrades of gravitational-wave detectors, it is imperative to find coating materials which reduce the thermal noise, whilst still meeting the desired optical requirements such as high reflectivity and low optical absorption.
Titania-doped silica has been identified as a coating material candidate which could potentially improve detector sensitivity. Collaboration with Glasgow University, we conducted studies into the mechanical and optical properties of highly-reflective coating stacks made of pure silica and titania doped silica, deposited via ion beam sputtering. Different doping concentrations of titania in the high-refractive index layers of our coating stacks were studied, through different heat treatment steps. This poster summarizes the current status of titania-doped silica as an alternative high-refractive index material for gravitational-wave detectors.

Presenter: SPAGNUOLO, Viola (Maastricht University)

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **65** Type: **not specified**

Development of cryogenic technologies for future gravitational-wave detectors

Tuesday, 24 October 2023 14:00 (20 minutes)

The discovery of gravitational waves paved the way for a new way of seeing the Universe, but above all, it paved the way for the development of new technologies.
Since the first gravitational-wave detection much progress has been made and the technology that allowed us to explore this new field has been renewed.
The cornerstone of this research remains the Michelson interferometer, whose sensitivity is, however, limited by the thermal noise to which its mirrors, called test masses, are subjected.
Thermal noise has been reduced so far thanks to the study of new mirror materials and this has contributed to the observation of new events in the cosmos.
Now, a new generation of gravitational wave detectors, such as the Einstein Telescope, is just around the corner and will operate at cryogenic temperatures.
Every new technology brings new challenges, and one of the most significant is the formation of a low density amorphous-state ice on the test mass surfaces. This ice layer grows with time and continuously changes the optical and mechanical properties of the mirrors.
The work presented on this poster illustrates the instruments and methodologies used to face these challenges, in particular the ice formation, starting from understanding how such ice affects the thermal noise.

Presenter: IANDOLO, Guido Alex (GWFP, Maastricht University (Nikhef))

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **66** Type: **Poster**

Advancing Gravitational-Wave Detection Through Ion Implantation for Low Thermal Noise Coatings

Tuesday, 24 October 2023 14:00 (20 minutes)

The forthcoming era of gravitational wave detectors, exemplified by the Einstein Telescope, demands unprecedented levels of sensitivity. Central to this progress is the deployment of cryogenic low-frequency interferometers, hinging on silicon as the mirror substrate material. A critical hurdle lies in mitigating coating thermal noise, a main limiting factor to detector precision. This project follows a new approach, using ion implantation to produce novel mirror coatings. Unlike traditional deposition methods, ion implantation creates coating layers inside the material instead of on the surface, potentially preserving the low noise characteristics of the crystalline silicon substrate. By implanting nitrogen ions into crystalline silicon, we aim to create low-index layers of silicon nitride (SiN) amidst the crystalline silicon, aiming to optimize the balance between optical absorption and thermal noise. Additionally, ion implantation promises to circumvent size limitations inherent in crystalline coatings, opening the door to larger mirrors needed for future gravitational wave detectors. The culmination of this endeavor lies in thermal noise tests conducted in the ETpathfinder facility. Here, the implanted mirror will be integrated and rigorously evaluated, providing a demonstration of the anticipated advancements. In conclusion, this project embarks on a transformative journey, leveraging ion implantation to revolutionize mirror coatings for gravitational wave detectors. Through extensive simulations, precise implantation, and comprehensive characterization, we aspire to refine the state-of-the-art in this critical facet of gravitational wave research.

Presenters: WOEHLER, Janis (Maastricht University); MASSARO, Luca (Maastricht University)

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **67** Type: **Poster**

Reducing Thermal Noise in Gravitational-Wave Detectors: Crystalline Top Layer for Amorphous Coatings

Tuesday, 24 October 2023 14:05 (20 minutes)

A gravitational wave detector can measure small periodic distortions in spacetime known as gravitational waves. Improvement in the sensitivity of these detectors can help gain new insight into physics. These instruments require mirror coatings made of low and high refractive index layers with very low coating thermal noise. Future detectors, such as the Einstein Telescope, will operate at cryogenic temperatures for which new coatings have to be developed. Promising materials are amorphous silicon as high-index material and silicon nitride as low-index material, which have low mechanical loss but too high optical absorption. Ways to reduce this absorption while keeping the mechanical loss low would be 1) optimizing the parameters for the chosen deposition processes 2) heat treatment of the coatings 3) studying doping processes and passivation of dangling bonds by using hydrogenation and fluorination 4) Investigating effects of the substrate on the coating performance. Using industrially available silicon on insulators (SOI) wafers with a device layer of the right thickness to be used as crystalline top layer of the coating. In this project, suitable bonding technologies to bond the SOI wafer, coated with improved materials, to the mirrors will be investigated as well as the etching procedure to have a final crystalline silicon top layer. Such a layer would reduce the light field inside the coating and consequently the coating absorption while showing negligible thermal noise.

Presenter: DIKSHA, Diksha (Maastricht university, GWFP (NIKHEF))

Session Classification: Posters

Track Classification: Instrumentation and R&D

Contribution ID: **68** Type: **not specified**

Status of LIGO-Virgo-Kagra

Monday, 23 October 2023 11:00 (15 minutes)

Presenter: GREEN, Anna

Session Classification: Instrumentation

Contribution ID: **69** Type: **not specified**

Status of LISA

Monday, 23 October 2023 12:05 (25 minutes)

Presenter: NELEMANS, Gijs (Radboud University Nijmegen)

Session Classification: Instrumentation