T 19: Gravitational Waves I

Time: Monday 16:15–18:15 Location: KS 00.005

T 19.1 Mon 16:15 KS 00.005

Integrating a Sagnac Interferometer into the Einstein Telescope — •Niklas Nippe and Achim Stahl — III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope (ET) aims to detect gravitational waves with unprecedented low-frequency sensitivity, where gravity gradients, so-called Newtonian Noise (NN), from seismic density fluctuations become a dominant limitation. While NN mitigation will most likely rely on arrays of seismometers measuring translational seismic motion to predict the resulting gravity perturbations, rotational motion carries complementary information that could improve NN prediction.

This talk explores the implementation of a Sagnac interferometer, a ring-laser system that would naturally provide high-precision rotational data in the low frequency regime, into one corner of the ET infrastructure. The area enclosed by the ring-laser setup would substantially increase compared to current state-of-the-art interferometers, hence an improvement in sensitivity by up to two orders of magnitude could be achieved. Finally, the potential contribution of such an integrated Sagnac interferometer to NN mitigation in the ET infrastructure is investigated.

T 19.2 Mon 16:30 KS 00.005

Parameter Estimation for long duration Gravitational Wave signals at the Einstein Telescope using Deep Learning — •Tobias Reike[1], Johannes Erdmann[1], and Achim Stahl[2] — [1]III. Physikalisches Institut A, RWTH Aachen University — [2]III. Physikalisches Institut B, RWTH Aachen University

The proposed Einstein Telescope will be a third-generation gravitational-wave detector, succeeding the current detectors LIGO, Virgo, and KAGRA. It aims to extend the sensitive frequency band toward both lower and higher frequencies and to improve the sensitivity of the current detectors by an order of magnitude. As a result, detected signals can be observed for much longer durations, ranging from minutes to hours, and the detection rate is expected to increase dramatically, reaching hundreds per day.

The analysis methods currently used to estimate source parameters from detected signals are extremely demanding in terms of computational resources, making them unsuitable for the substantially larger data volume anticipated for the Einstein Telescope. Consequently, new and more efficient methods are under development. We present a deep-learning-based approach to parameter estimation that relies on conditional normalizing flows, along with our ongoing work on the analysis of long-duration signals, which pose a particular challenge.

T 19.3 Mon 16:45 KS 00.005

Prospects for Coincident Detection of Short Gamma-Ray Bursts with IceCube-Gen2 and the Einstein Telescope — •Rajanvir Singh[1], Anna Franckowiak[2], Philipp Fürst[1], Christopher Wiebusch[1], and Angela Zegarelli[2] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]Astronomisches Institut, Ruhr-Universität Bochum

With the coincident observation of a short gamma-ray burst (sGRB) and gravitational waves from a neutron star binary merger (NSM) in 2017, these objects have become a primary target for multi-messenger astronomy. In this context, measuring also coincident neutrinos from these NSMs is decisive for probing hadronic processes in these violent environments. With enhanced sensitivity of next-generation neutrino and gravitational wave observatories, such as IceCube-Gen2 and the Einstein Telescope, the chances of observing coincidences improve. Based on previous work we will discuss simulated neutron star mergers with the goal of estimating detection rates of IceCube-Gen2 and the Einstein Telescope and a joint detection rate.

T 19.4 Mon 17:00 KS 00.005

Probing binary black hole merger populations in AGN disks through future IceCube-Gen2 and Einstein Telescope observations — •Tista Mukherjee[1], Mainak Mukhopadhyay[2], Foteini Oikonomou[3], Andreas Haungs[1], and Ralph Engel[1] — [1]Institute for Astroparticle Physics (IAP), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Astrophysics Theory Department, Theory Division, Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA — [3]Institutt for fysikk, NTNU, Trondheim, Norway

The detection of astrophysical neutrinos and gravitational waves (GWs) has ushered in a new era of multi-messenger astroparticle physics. While coincident detections of GW and neutrinos alongside electromagnetic signals have already been achieved in separate instances, no common source of GW and neutrinos has yet been identified. To address the implications of non-detection, this work investigates the prospects for identifying binary black hole mergers embedded in AGN disks as common GW-neutrino sources with next-generation facilities, e.g., the Einstein Telescope and IceCube-Gen2. For sources located in the Northern Hemisphere, the detection significance is quantified for both individual mergers and their populations, to be seen by the Einstein Telescope. It is found that, even with improved sensitivity of next-generation detectors, catalogue searches have limited potential. In contrast, stacking offers a viable path to uncover a population of common GW-neutrino sources in the future.

T 19.5 Mon 17:15 KS 00.005

Investigating the Visibility of Newtonian Noise in the Einstein Telescope Null Stream — •Josie Altenhövel, Johannes Erdmann, and Patrick Schillings — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope (ET) is a planned third-generation gravitational-wave observatory designed to surpass the sensitivity of current detectors. Its triangular layout provides three interferometer signals with fixed geometric relations, enabling the construction of a null stream in which any gravitational-wave contribution is expected to cancel, while all non-gravitational disturbances are expected to remain with finite amplitude. Any event that appears in the null stream can therefore be identified as noise and is excluded from astrophysical interpretation. Among the relevant disturbances is Newtonian noise (NN), which originates from gravitational field fluctuations caused by seismic density variations in the surrounding rock and at surfaces. NN is expected to dominate the low-frequency regime that is critical for ET. To investigate its behavior, simulations are used to generate three-dimensional seismic fields and the corresponding NN forces acting on the ET test masses. A broad range of NN configurations is examined to determine under which conditions NN could produce signatures that disappear in the null-stream construction. The study thereby evaluates the diagnostic role of the ET null stream for an estimate of NN at future low-frequency gravitational-wave observatories.

T 19.6 Mon 17:30 KS 00.005

Reducing Wind Turbine Vibrations for the Einstein Telescope in the EMR Region — •Tom Niggemann and Achim Stahl — III. Physikalisches Institut B RWTH Aachen University

The planned realization of the Einstein Telescope in the EMR region (Euregio Meuse-Rhine) requires a significant reduction of environmental disturbances, particularly those caused by seismic waves and the resulting Newtonian Noise. A significant contribution to these disturbances originates from the vibration modes of wind turbines, whose foundation and tower motions propagate through the ground and may compromise the sensitivity of the gravitational-wave detector. To mitigate these effects, several engineering measures are being investigated: the enlargement of foundations to lower eigenfrequencies and improve ground coupling, as well as the implementation of tuned mass dampers to suppress critical vibration modes. Complementary numerical simulations and studies are conducted to validate the effectiveness of these approaches. The overarching goal is to develop a robust vibration-reduction concept that reconciles the integration of renewable energy with the extreme requirements of gravitational-wave research.

T 19.7 Mon 17:45 KS 00.005

Towards a more realistic Seismometer Position Optimization for Newtonian Noise Mitigation at the Einstein Telescope — •Patrick Schillings and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope is a third-generation, underground gravitational wave detector that will allow us to measure gravitational waves with significantly improved precision. Its 'xylophone' arrangement is designed to extend the frequency range down to a few Hertz. To improve the sensitivity of the low-frequency interferometer, one needs to mitigate the gravitational effect of density fluctuations in the surrounding rock caused by seismic activity, which result in so-called Newtonian noise. To predict the Newtonian noise, an array of seismometers will be installed around the interferometer mirrors. Expensive boreholes will have to be drilled in order to place these seismometers, which will limit the total number of seismometers that can be placed for a given budget. Therefore, the available resources should be used optimally in terms of predicting the Newtonian noise from the seismometer data. Until now, optimizations were based on a simplifed, analytical model of the seismic wave field. In this talk, I introduce a simulation of seismic waves that allows to lift several assumptions of this model. It provides a stepstone towards more complex site-specific geological models to be used for seismometer position optimization.

T 19.8 Mon 18:00 KS 00.005

Stimulated Emission or Absorption of Gravitons by Light
— •Ralf Schützhold — Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We study the exchange of energy between gravitational and electromagnetic waves in an extended Mach-Zehnder or Sagnac type geometry that is analogous to an optical Weber bar. In the presence of a gravitational wave (such as the ones measured by the Laser Interferometer Gravitational Wave Observatory), we find that it should be possible to observe (via interference or beating effects after a delay line) signatures of stimulated emission or absorption of gravitons with present-day technology. Apart from marking the transition from passively observing to actively manipulating such a natural phenomenon, this could also be used as a complementary detection scheme. Nonclassical photon states may improve the sensitivity and might even allow us to test certain quantum aspects of the gravitational field.

[1] R. Schützhold, *Stimulated Emission or Absorption of Gravitons by Light*, Phys. Rev. Lett. **135**, 171501 (2025)