T 39: Gravitational Waves II

Time: Tuesday 16:15–17:45 Location: KS 00.005

T 39.1 Tue 16:15 KS 00.005

Cavity-Based High-Frequency Gravitational-Wave Detection at GravNet — •Stefan Horodenski, Kristof Schmieden, Matthias Schott, and Swarangee Saraf — University of Bonn, Physikalisches Institut, Bonn, Germany

The GravNet collaboration aims to perform the first detection of high-frequency gravitational waves (HFGWs) in the GHz range (1-10 GHz), which could provide sensitivity to primordial black holes, one candidate for dark matter.

GravNet is a network of high-frequency gravitational-wave detectors currently under construction. One detector concept exploits the inverse Gertsenshtein effect, in which gravitational waves induce electromagnetic signals in small, strongly magnetized radio-frequency (RF) cavities.

The experimental setup comprises a cryogenic cylindrical RF cavity mounted inside a 12 T superconducting magnet and coupled to an ultra-low-noise readout chain, whose first amplification stage is a traveling-wave parametric amplifier (TWPA), enabling near-quantum-limited noise performance. We discuss the prospects of RF-based gravitational-wave searches and present the development of a new experimental setup at Bonn, including optimization of the prototype cavity and characterization of the TWPA.

T 39.2 Tue 16:30 KS 00.005

Challenge of High-Frequency Gravitational Waves Detection — •Gudrid Moortgat-Pick z. Hd. Lipps[1,2], Gudrid Moortgat-Pick z. Hd. Lipps[1], Gudrid Moortgat-Pick z. Hd. Lipps[1], Gudrid Moortgat-Pick z. Hd. Lipps[1], Gudrid Moortgat-Pick z. Hd. Lipps[2], and Gudrid Moortgat-Pick z. Hd. Lipps[2] — [1]University of Hamburg — [2]Am alten Tor 11

High frequency gravitational waves (GWs) remain unexplored messengers of new physics. Proposed sources in the MHz - GHz band include primordial black hole mergers, black hole superradiance and several stochastic backgrounds.Our collaboration is working on tapping into this source by employing superconducting microwave cavities for high precision measurements of harmonic displacements.

The talk give an actual status report on the experimental as well as the theoretical new developments including the measurements as well as background considerations.

T 39.3 Tue 16:45 KS 00.005

ML based detection strategies for high frequency GWs. — •Swarangee Saraf[1], Matthias Schott[2], Kristof Schmieden[2], Stefan Horodenski[2], and Christian Gottschlich[2] — [1]University of Bonn, Germany — [2]Physikalisches Institute, University of Bonn, Germany

The Gravitational Wave Network (GravNet) is a network of high frequency gravitational wave detectors currently under construction. The detector concept relies on the resonant conversion of gravitational wave energy into electromagnetic energy, using the inverse Gertsenshtein effect. In this talk we will discuss challenges in detecting high frequency GWs and explore solutions by using machine learning techniques.

T 39.4 Tue 17:00 KS 00.005

Newtonian Noise in non-spherical caverns for the Einstein Telescope — •Valentin Tempel, Jörg Pretz, and Achim Stahl — III. Physikalisches Institut, RWTH Aachen

The Einstein Telescope (ET), a proposed third-generation gravitational-wave detector, aims to exceed the sensitivity of current interferometers, enabling the observation of significantly fainter signals. Achieving the desired performance requires a precise understanding and likely also mitigation of Newtonian Noise (NN), which is expected to be a significant contribution to the ET noise budget in the 1-10 Hz region. One important NN component originates from seismic-induced density fluctuations in the surrounding rock, as well as from the motion of cavern walls, producing fluctuating gravitational forces on the interferometer test masses. In the past, simplified models with spherical caverns have often been used as a theoretical order-of-magnitude estimation for NN, but those models are not generally representative of realistic underground environments. We present how cavern geometry affects the coupling of NN from seismic waves to the ET mirrors. Using analytical and numerical methods, we quantify how deviations from spherical symmetry and variations in cavern size modify the NN coupling transfer functions. The results highlight the limitations of simplified models and emphasize the importance of accurate models for reliable NN predictions in the Einstein Telescope.

T 39.5 Tue 17:15 KS 00.005

Newtonian Noise mitigation for the Einstein Telescope using Deep Learning — •Jonathan Kuckert, Jan Kelleter, Patrick Schillings, and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

In the past, gravitational wave interferometers were not able to measure low frequency gravitational waves. The Einstein-Telescope (ET) is a proposed third-generation underground gravitational wave interferometer. For the first time, ET will enable measurements in the 1-10 Hz region. In this region, Newtonian Noise (NN), perturbations in the gravitational field due to density fluctuations in the underground, is the predicted dominant noise source. As a gravitational phenomenon NN, cannot be shielded. Therefore, the most promising mitigation strategy is based on seismometer arrays. The seismometers surround the interferometer mirrors and the gravitational noise on the mirrors is predicted using the seismometer data. For this kind of prediction, Wiener Filters (WFs) were deployed as a standard solution in the past. Based on simulations of simplified seismic events, it has been shown that Deep Learning methods, specifically Graph Neural Networks (GNNs) can match and outperform WFs. In this talk we present further improvements in mitigation and first steps towards optimising seismometer positions using Machine Learning.

T 39.6 Tue 17:30 KS 00.005

Testing Noise Mitigation Techniques for Future Gravitational Wave Detectors — Markus Bachlechner, Johannes Erdmann, •Tim J. Kuhlbusch, Achim Stahl, and Jochen Steinmann — III. Physikalisches Institut, RWTH Aachen

Future gravitational wave (GW) detectors like the Einstein Telescope aim to decrease the detector noise to increase the precision of measurements and to detect weaker signals. To measure the minuscule length changes induced by GWs, extremely low vibration levels for the test masses are required. New noise sources become relevant in reducing the residual vibrations of the test masses. Gravitational couplings from density fluctuations of the surrounding material, called gravity gradient noise, can not be shielded. Therefore, predicting the coupled noise from inertial sensors is essential to reduce the impact in the 1 to 10 Hz range.

Wiener filters are a simple and robust approach to predicting coupled noise. However, the classic Wiener filter can not adapt to variations in the amplitude of the coupled noise. As variations in the amplitude over time are expected for the ambient noise sources in GW detectors, an adaptive filter is required for optimal performance. This talk discusses adaptive filtering options and presents the evaluation in a small-scale interferometer.