GR 8: Gravitational Waves II

Time: Wednesday 13:45–15:15 Location: KH 01.016

GR 8.1 Wed 13:45 KH 01.016

interaction between gravitational waves and condensed matter systems — •Michel Paulsen[1], Gudrid Moortgat-Pick[1,2], Andreas Ringwald[2], and Tom Krokotsch[1] — [1]University of Hamburg — [2]DESY

Gravitational waves have established themselves as a key tool for investigating compact astrophysical sources, but so far they have been limited to a lower frequency range. High-frequency gravitational waves (HFGW) are of particular theoretical interest, as they could potentially provide access to previously unexplored physical processes. The talk covers theoretical investigations of the interaction of gravitational waves with condensed matter systems, with a focus on high-frequency regimes. The focus is on specific physical mechanisms through which HFGW could couple with structured matter, as well as their consequences for alternative approaches to investigating such signals. Matter systems that are suitable for corresponding theoretical analyses, including superconducting systems, are considered as a frame of reference.

GR 8.2 Wed 14:00 KH 01.016

Mission Concepts for future space-based Gravitational Wave Detectors — •Jones Rosario — MPI for Gravitational Physics (AEI), Hannover, Germany

Gravitational waves are ripples in space-time caused by some of the most energetic processes in our universe. Since the first detection by LIGO in 2015, over 200 further signals have been observed. In 2035, the ESA-led space mission LISA is set to launch and will have it's highest sensitivity in the mHz band. With this, LISA's sensitivity will lie between the high-frequency window (hertz to kilohertz) of ground based detectors such as LIGO and Virgo, and the nano-hertz regime probed by PTAs. However, these detectors will not cover the gravitational wave spectrum entirely. Particularly, there are gaps in the decihertz and the microhertz regime, which could be addressed by future space missions. In the context of ongoing efforts to propose mission concepts to ESA for the 2050s, we will discuss mission concepts proposed in literature that aim to probe these bands. We further extend on this and present current developments towards realistic designs with respect to technical feasibility and affordability.

GR 8.3 Wed 14:15 KH 01.016

Gravitational wave backgrounds from trapped axion-like particles — •Daniel Schmitt — Goethe University Frankfurt

Axion-like particles (ALPs) are among the most promising dark matter candidates. While laboratory experiments and astrophysical observations have excluded parts of the viable ALP parameter space, the regime of large ALP decay constants, where the ALP becomes invisible, remains hard to access experimentally. I will discuss the conditions under which such invisible ALPs can generate a sizable primordial gravitational wave (GW) background. In particular, I will focus on ALP production via trapped misalignment, where the oscillations of the pseudoscalar are delayed compared to the conventional misalignment scenario. This can trigger resonances in the equation of motion of both the ALP and a gauge field coupled to the ALP, leading to the exponential growth of horizon-sized fluctuations in the early Universe. Such large anisotropies source stochastic GWs, enabling to probe a large part of the ALP parameter space through future GW observatories.

GR 8.4 Wed 14:30 KH 01.016

Predicting gravitational wave observations for next-generation detectors — •Per-Ingmar Laurens Schrake[1,2] and Frank Ohme[1,2] — [1]Max Planck Institute for Gravitational Physics — [2]Leibniz University Hannover

The detection of gravitational waves from merging compact binaries has revolutionized astronomy since the first observation in 2015, with the current GWTC-4.0 catalog containing 161 events. A new generation of significantly more sensitive detectors, such as the Einstein Telescope (ET) and Cosmic Explorer (CE), is already being planned. But what will these future detectors actually be able to measure in detail? This talk examines what predictions about future gravitational wave observations can be derived from the currently available population statistics. To answer this, a synthetic merger population is generated by randomly sampling from the parameter distributions reported in GWTC-4.0. Subsequently, the corresponding gravitational waveforms are generated with state-of-the-art models and evaluated depending on the sensitivity curve of next-generation detectors. The statistical distribution of the resulting signal-to-noise ratio is analyzed to estimate the anticipated occurrence of very strong signals. The framework further enables systematic comparisons among different population models and confusion noise estimates. Under realistic assumptions regarding population properties and detector sensitivities, it becomes apparent that ET enables the near-complete detection of merging compact binaries within the local universe.

GR 8.5 Wed 14:45 KH 01.016

Vacuum, surface monitoring and cleaning experiment for Einstein Telescope — •Markus Schulz-Ritz, Joachim Wolf, Adrian Schwenck, Ralph Engel, Judith Schneider, and Hendrik Weingardt for the Einstein Telescope-Collaboration — Karlsruhe Institute for Technology, Karlsruhe, Germany

The Einstein Telescope (ET) will be a third generation gravitational wave detector, consisting of a set of low frequency and high frequency interferometers. In order to mitigate thermal noise, the mirrors for the low frequency interferometer are required to be cooled down to cryo temperatures. This leads to freezing of residual gas from the vacuum chamber onto the mirror surface. This will affect the required cooling power and the sensitivity of ET. Hence R&D measurements at cryogenic temperatures are being prepared, investigating the formation of ice layers on the mirror from different gases (CO2, water, nitrogen,...) using ellipsometry and quartz micro balances (QMB) for monitoring the thickness of the layer. Further research will include the testing of different in-situ cleaning procedures of silicon surfaces with methods, such as argon plasma cleaning, low-energy electrons and UV light. The talk will be about the setup at KIT and will present first results.

GR 8.6 Wed 15:00 KH 01.016

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)