Ultra-high frequency gravitational waves: where to next ?

Report of Contributions

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

Prospects for HFGW searches with the axion experiments ALPS II and BabyIAXO

Wednesday, December 6, 2023 3:30 PM (25 minutes)

At DESY in Hamburg, axions search experiments not relying on the dark matter paradigm are taking data (ALPS II) or have good prospects to start construction soon (BabyIAXO). Due to the similarity of axion-photon and GW-photon conversions in background magnetic fields, both experiments will also be sensitive to high frequency gravitational waves (HF-GW). The status of ALPS II and BabyIAXO as well as potential dedicated HF-GW searches will be sketched.

Primary author: LINDNER, Axel

Presenter: LINDNER, Axel

Session Classification: EM-GW detectors

Contribution ID: **2** Type: **not specified**

High Temperature Effects in the Cosmic Gravitational Microwave Background

Thursday, December 7, 2023 11:45 AM (12 minutes)

The thermal plasma in the early universe produced a guaranteed stochastic gravitational wave (GW) background, which peaks today in the microwave regime and was dubbed the cosmic gravitational microwave background (CGMB). The CGMB spectrum encodes fundamental information about particle physics and gravity at ultra high energies. In particular, one can determine from the CGMB spectrum the maximum temperature of the universe and the effective degrees of freedom at the maximum temperature.
In previous works only single graviton production processes that contribute to the CGMB have been considered. In this talk I show that graviton pair production processes can also yield a significant contribution to the CGMB spectrum if the ratio between the maximum temperature and the Planck mass, $T_{\rm max}/m_{\rm p}$, divided by the internal coupling in the heat bath is large enough.
In addition I discuss how quantum gravity effects appear in single graviton production processes and are smaller by a factor $(T_{\rm max}/m_{\rm p})^2$ than the leading order contribution.

Primary authors: SPERANZA, Enrico (University of Illinois at Urbana-Champaign); GHIGLIERI, Jacopo; SCHUETTE ENGEL, Jan (UC Berkeley)

Presenter: SCHUETTE ENGEL, Jan (UC Berkeley)

Session Classification: Theory

Contribution ID: **3** Type: **not specified**

Bremsstrahlung High-frequency Gravitational Wave Signatures of High-scale Non-thermal Leptogenesis

Friday, December 8, 2023 9:45 AM (12 minutes)

Inflaton seeds non-thermal leptogenesis by pair producing right-handed neutrinos in the seesaw model. We show that the inevitable graviton bremsstrahlung associated with inflaton decay can be a unique probe of non-thermal leptogenesis. The emitted gravitons contribute to a high-frequency stochastic gravitational waves background with a characteristic fall-off below the peak frequency. Besides leading to a lower bound on the frequency (f⊠1011 Hz), the seesaw-perturbativity condition makes the mechanism sensitive to the lightest neutrino mass. For an inflaton mass close to the Planck scale, the gravitational waves contribute to sizeable dark radiation, which is within the projected sensitivity limits of future experiments such as CMB-S4 and CMB-HD.

Primary author: GHOSHAL, Anish

Presenter: GHOSHAL, Anish

Session Classification: Theory

Contribution ID: **5** Type: **not specified**

Detecting single gravitons with quantum sensing

Tuesday, December 5, 2023 2:45 PM (12 minutes)

The quantization of gravity is widely believed to result in gravitons – particles of discrete energy that form gravitational waves. But their detection has so far been considered impossible. Here we show that signatures of single gravitons can be observed in laboratory experiments 1. We show that stimulated and spontaneous single-graviton processes can become relevant for massive quantum acoustic resonators and that stimulated absorption can be resolved through continuous sensing of quantum jumps. We analyze the feasibility of observing the exchange of single energy quanta between matter and gravitational waves. Our results show that single graviton signatures are within reach of experiments. In analogy to the discovery of the photo-electric effect for photons, such signatures can provide the first experimental evidence of the quantization of gravity.

Our work is outlined in
G. Tobar, S. K. Manikandan, T. Beitel and I. Pikovski, arXiv:2308.15440

Corresponding author: pikovski@stevens.edu

Primary authors: TOBAR, Germain; MANIKANDAN, Sreenath K. (Stockholm University and Nordita); BEITEL, Thomas (Stevens Institute of Technology); PIKOVSKI, Igor (Stevens Institute of Technology and Stockholm University)

Presenter: TOBAR, Germain

Session Classification: Theory

Contribution ID: **6** Type: **not specified**

Detection of ultra high frequency gravitational waves from compact binary coalescenses with resonant cavities

Friday, December 8, 2023 10:00 AM (12 minutes)

In this talk I will try to clarify the situation about astrophysical sources that might be observed with haloscope experiments like GrAHal, sensitive to gravitational waves in the 1-10 GHz band. The GrAHal setup is taken as a benchmark. We follow a very pedagogical path so that the full analysis can easily be used by the entire community who might not be familiar with the theoretical framework. Different relevant physical regimes are considered in details and some formulas encountered in the literature are revised. The distances that can be probed and expected event rates are carefully evaluated, taking into account degeneracies between physical parameters. We show where experimental efforts should be focused to improve the sensitivity.

Primary author: Prof. GARCIA-BELLIDO, Juan (IFT-UAM/CSIC)

Presenter: Prof. GARCIA-BELLIDO, Juan (IFT-UAM/CSIC)

Session Classification: Theory

Contribution ID: **7** Type: **not specified**

Graviton detection and the quantization of gravity

Tuesday, December 5, 2023 3:00 PM (12 minutes)

A key dividing line in the dark matter community is between the wave and particle regimes. This division can be applied to any bosonic state, and for gravitational energy density the boundary cuts right through the ultra-high frequency regime. I will discuss the implications of this for instruments looking to detect a signal in the regime where gravity is a dilute gas of gravitons, and explain why contrary to what analogies with the photoelectric effect might suggest, a detection in that parameter space would not prove gravity was quantized.

Primary author: RODD, Nicholas Llewellyn (CERN)

Presenter: RODD, Nicholas Llewellyn (CERN)

Session Classification: Theory

Contribution ID: **8** Type: **not specified**

Gravitational waves from high-power twisted light

Friday, December 8, 2023 9:30 AM (12 minutes)

Recent advances in high-energy and high-peak-power laser systems have opened up new possibilities for fundamental physics research.
I propose to discuss the potential of twisted light for the generation of gravitational waves in the high frequency regime.
Focusing on Bessel beams, analytic expressions and numerical computations for the generated metric perturbations and associated powers are presented. Notably, we show that properties of the generated gravitational waves, such as frequency, polarisation states and direction of emission, can be controllable by the laser pulse parameters and optical arrangements.
Based on: https://arxiv.org/pdf/2309.04191.pdf

Primary author: MARTINEAU, Killian (Laboratoire de Physique Subatomique et de Cosmologie)

Presenter: MARTINEAU, Killian (Laboratoire de Physique Subatomique et de Cosmologie)

Session Classification: Theory

Contribution ID: **9** Type: **not specified**

Sensing High Frequency Gravitational Waves with Acoustic Resonators: an update on the MAGE experiment

Tuesday, December 5, 2023 12:15 PM (12 minutes)

The Multimode Acoustic Gravitational wave Experiment (MAGE) is a high frequency gravitational wave detection experiment 1 that utilises quartz bulk acoustic wave resonators as precision strain sensors. In its first stage, the experiment features two near-identical quartz bulk acoustic wave resonators that act as strain antennas with spectral sensitivity as low as 6.6×10^{-21} [strain] $/\sqrt{\text{Hz}}$ in multiple narrow bands across MHz frequencies. As a natural continuation of the initial pathfinding run [2] in which strong background features were observed at $\approx$ 5 MHz; MAGE features various hardware upgrades in order to disentangle such signals from target gravitational events. The primary goals of MAGE will be to explore potential gravitational signals sourced by physics beyond that of the standard model, as well as identifying the source of the events seen in its predecessor run. Here we present an update and the current status of the MAGE experiment.

1 https://arxiv.org/abs/2307.00715
[2] https://arxiv.org/abs/2102.05859

Primary author: CAMPBELL, William

Co-authors: GORYACHEV, Maxim; TOBAR, Michael

Presenter: CAMPBELL, William

Session Classification: Mechanical resonators

Contribution ID: **11** Type: **not specified**

Ultra-high frequency gravitational waves from inflaton decay

Thursday, December 7, 2023 11:30 AM (12 minutes)

Since the models of inflation compatible with CMB data require non-renormalizable inflaton potentials, it is natural to have extra couplings between inflaton and gravitons. The suppression scale of such operators can well be lower than the Planck scale. Due to these couplings, inflaton can produce high frequency gravitons during reheating due to both decay and bremsstrahlung process. In my talk, I will present results of computation of the gravitational wave signal strength coming from these processes, as well as graviton contribution to the number of relativistic degrees of freedom. Remarkably, in the case of low reheating temperature, even Planck-suppressed operators lead to potentially measurable contribution to the dark radiation.

Primary author: TOKAREVA, Anna (Hangzhou Institute for Advanced Study & ICTP-AP Centre Beijing/Hangzhou)

Presenter: TOKAREVA, Anna (Hangzhou Institute for Advanced Study & ICTP-AP Centre Beijing/Hangzhou)

Session Classification: Theory

Contribution ID: **12** Type: **not specified**

Partially-levitated membranes for high-frequency gravitational wave (HFGW) detection

Tuesday, December 5, 2023 12:00 PM (12 minutes)

Patterned thin films that are freely suspended from a silicon chip (i.e., membranes) are some of the lowest-loss mechanical oscillators.

As such, they provide an exceptional level of isolation from the noisy environment, similar to what has been achieved with levitated nanoparticles.

Here, I will present a concept for a HFGW detector, which corresponds to a Michelson interferometer with a membrane incorporated in each arm cavity.

In addition to explaining the underlying operating principle, I will provide details on achieving a sensitivity comparable to the target for the Levitated Sensor Detector, which relies on optically levitated stacks instead of membranes. (see dedicated talks).

In this regard, a particular focus will be on realizing suitable membranes, which requires significantly reducing their intrinsic loss.

Primary author: REINHARDT, Christoph (DESY)

Presenter: REINHARDT, Christoph (DESY)

Session Classification: Mechanical resonators

Contribution ID: **13** Type: **not specified**

Towards coordinate independent estimates for electro-magnetic GW detectors

Thursday, December 7, 2023 12:00 PM (12 minutes)

There has recently been an increased interest in electro-magnetic GW detectors, due to the first detections of GWs and the rapid evolution of the technology driven by searches for light dark matter. The question how to calculate the response of e.g. a cavity to a GW has been debated since the 80s and the current understanding is that the usage of a special frame, the proper detector frame, is necessary to get the correct result. This idea is however somewhat disturbing, since coordinate invariance lies at the heart of general relativity, and criticism of this approach is therefore as old as the approach itself. We hope to clarify some of the issues leading to this apparent contradiction.

Primary author: RATZINGER, Wolfram (Weizmann Institute)

Presenter: RATZINGER, Wolfram (Weizmann Institute)

Session Classification: Theory

Contribution ID: **15** Type: **not specified**

High-Frequency Gravitational Waves in Electromagnetic Waveguides

Tuesday, December 5, 2023 2:30 PM (12 minutes)

The interaction between a very-high-frequency gravitational wave (VHFGW) and an electromagnetic wave (EMW) in a rectangular waveguide is discussed in the weak field limit. The background EMW is assumed to be initially in the TE10 mode along the waveguide. It is then shown that a VHFGW, having the same frequency and direction of propagation of the EMW, induces through the waveguide a TE mode with a frequency doubled when compared to the original EMW frequency. In that respect, the GW acts similar to a non-linear medium, giving rise to a Second Harmonic Generation (SHG) effect.

Primary author: SORGE, Francesco

Presenter: SORGE, Francesco

Session Classification: Theory

Contribution ID: **17** Type: **not specified**

Detection of high-frequency gravitational waves using high-energy pulsed lasers

Wednesday, December 6, 2023 4:00 PM (12 minutes)

We propose a new method for detecting high-frequency gravitational waves (GWs) using high-energy pulsed lasers. Through the inverse Gertsenshtein effect, the interaction between a GW and the laser beam results in the creation of an electromagnetic signal. The latter can be detected using single-photon counting techniques. We present the minimal strain of a detectable GW which only depends on the laser parameters. Interestingly, we find that a resonance occurs in this process when the frequency of the GW is twice the frequency of the laser. With this method, the ultra-high GW-frequency range 10^{13} - 10^{19} Hz is explored non-continuously for strains h $gtrsim 10^{-20}$ for current laser systems and can be extended to h $gtrsim 10^{-26}$ with future generation facilities.

Presenter: VACALIS, Georgios

Session Classification: EM-GW detectors

Contribution ID: **18** Type: **not specified**

Searching for Axions and High-Frequency Gravitational Waves with ABRACADABRA-10cm

Wednesday, December 6, 2023 10:00 AM (25 minutes)

ABRACADABRA-10cm has had great success as a lumped-element axion dark matter pathfinder experiment. Now, using the electrodynamics of gravitational waves and a simple change of pickup structures, we are using the ABRACADABRA detector to search for high-frequency gravitational wave in the kHz to MHz range. These higher frequencies may indicate signs of in-spiraling primordial black holes, or other beyond the standard model phenomena. With careful calibration used to distinguish between the two signals, we introduce the first simultaneous search for both axions and gravitational waves. I will present on the design and first data from the ABRACADABRA-10cm high-frequency gravitational wave search.

Presenter: PAPPAS, Kaliroe (Massachusetts Institute of Technology, Laboratory For Nuclear Science)

Session Classification: EM-GW detectors

Contribution ID: **19** Type: **not specified**

Heterodyne detection

Monday, December 4, 2023 12:00 PM (25 minutes)

Presenter: EJLLI, Aldo

Session Classification: EM-GW detectors

Contribution ID: **20** Type: **not specified**

SRF cavities

Monday, December 4, 2023 9:45 AM (25 minutes)

Presenter: ELLIS, Sebastian (Universite de Geneve (CH))

Session Classification: EM-GW detectors

Contribution ID: **21** Type: **not specified**

The MAGO cavity and prospects for HFGW searches

Monday, December 4, 2023 10:15 AM (25 minutes)

The former MAGO collaboration, led by INFN Genoa, developed in the past SRF cavities in order to perform R&D with the aim to search for gravitational waves. In a collaborative effort, DESY/U.Hamburg and Fermilab continues this R&D programme. Since July the MAGO cavity is at DESY for measurements and matching simulations to characterise the cavity before surface treatment and cold measurements at Fermilab. The aim is to use this cavity for a first GW search and to develop new cavities and the necessary dedicated cryostat and suspension system for improved GW measurements in the future.

Presenter: PETERS, Krisztian (Deutsches Elektronen-Synchrotron (DE))

Session Classification: EM-GW detectors

Contribution ID: **22** Type: **not specified**

Levitated sensor detectors

Tuesday, December 5, 2023 9:30 AM (25 minutes)

Presenter: GERACI, Andrew

Session Classification: Mechanical resonators

Contribution ID: **23** Type: **not specified**

Superradiance

Tuesday, December 5, 2023 10:00 AM (25 minutes)

Presenter: SPRAGUE, Jacob

Session Classification: Theory

Contribution ID: **24** Type: **not specified**

Bulk Acoustic Wave devices

Tuesday, December 5, 2023 11:30 AM (25 minutes)

Presenter: TABARELLI DE FATIS, Tommaso (Universita & INFN, Milano-Bicocca (IT))

Session Classification: Mechanical resonators

Contribution ID: **25** Type: **not specified**

Magnetosphere conversion

Thursday, December 7, 2023 9:30 AM (25 minutes)

Presenter: LIU, Tao (The Hong Kong University of Science and Technology)

Session Classification: Theory

Contribution ID: **26** Type: **not specified**

Axion haloscopes

Wednesday, December 6, 2023 9:30 AM (25 minutes)

Presenter: GARCIA CELY, Camilo Alfredo (Technical University Munich)

Session Classification: EM-GW detectors

Contribution ID: **27** Type: **not specified**

Atomic precision measurements

Wednesday, December 6, 2023 11:30 AM (25 minutes)

Presenter: FUCHS, Elina

Session Classification: EM-GW detectors

Contribution ID: **28** Type: **not specified**

Pulsed lasers

Wednesday, December 6, 2023 12:00 PM (25 minutes)

Presenter: GREGORI, Gianluca (University of Oxford)

Session Classification: EM-GW detectors

Contribution ID: **29** Type: **not specified**

Mega- Hertz Gravitational Waves from Neutron Star Mergers

Friday, December 8, 2023 11:30 AM (25 minutes)

Presenter: SANCHEZ-GARITAONANDIA, Mikel

Session Classification: Theory

Contribution ID: **30** Type: **not specified**

SQMS

Monday, December 4, 2023 11:30 AM (25 minutes)

Presenter: GIACCONE, Bianca (Fermi National Accelerator Laboratory)

Session Classification: EM-GW detectors

Contribution ID: **31** Type: **not specified**

Primordial black holes: a dark matter candidate in the ultra-high frequency gravitational wave window

Wednesday, December 6, 2023 2:00 PM (1 hour)

Primordial Black Holes might have originated in the early universe from the collapse of large overdensities and could constitute a sizeable portion of dark matter. Recently, they have gained considerable attention because of the various gravitational wave (GW) signatures associated with this scenario, making them testable with current and future GW experiments. In this talk, I will provide an overview of the current status of GW searches for this distinctive dark matter candidate, and discuss, in particular, the GW signatures that could be present in the ultra-high frequency window.

Presenter: FRANCIOLINI, Gabriele (CERN)

Session Classification: Theory

Contribution ID: **32** Type: **not specified**

Overview of magnon-based concepts

Thursday, December 7, 2023 2:30 PM (12 minutes)

Presenter: ITO, Asuka (Tokyo institute of technology)

Session Classification: Theory

Contribution ID: **33** Type: **not specified**

A new gravitational wave plotter

Thursday, December 7, 2023 2:45 PM (12 minutes)

Presenter: TAMARIT, Carlos (Technische Universität München)

Session Classification: Theory

Contribution ID: **34** Type: **not specified**

Q&A

Monday, December 4, 2023 10:40 AM (20 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **35** Type: **not specified**

Q&A

Wednesday, December 6, 2023 12:30 PM (30 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **36** Type: **not specified**

Q&A

Monday, December 4, 2023 12:30 PM (30 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **37** Type: **not specified**

Q&A

Tuesday, December 5, 2023 10:30 AM (30 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **38** Type: **not specified**

Q&A

Tuesday, December 5, 2023 12:30 PM (30 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **39** Type: **not specified**

Q&A

Tuesday, December 5, 2023 3:15 PM (45 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **40** Type: **not specified**

Q&A

Wednesday, December 6, 2023 10:30 AM (30 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **41** Type: **not specified**

Q&A

Wednesday, December 6, 2023 4:15 PM (30 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **42** Type: **not specified**

Q&A

Thursday, December 7, 2023 12:15 PM (45 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **43** Type: **not specified**

Q&A

Thursday, December 7, 2023 3:00 PM (15 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **44** Type: **not specified**

Q&A

Friday, December 8, 2023 10:15 AM (45 minutes)

Presenter: DOMCKE, Valerie (CERN)

Session Classification: Q&A session

Contribution ID: **46** Type: **not specified**

comparing sensitivities

Thursday, December 7, 2023 10:00 AM (1 hour)

Presenter: TOBAR, Michael (The University of Western Australia)

Session Classification: Topical discussion