SCIENCES & BIOENGINEERING SCIENCES

The Research Group
Elementary Particle Physics

has the honor to invite you to the public defence of the PhD thesis of

Kevin Turbang

to obtain the degree of Doctor of Sciences

Joint PhD with Universiteit Antwerpen

Title of the PhD thesis:

The Stochastic Gravitational-Wave Background: from Models to Observations

Promotors:
Prof. dr. Alberto Mariotti (VUB)
Prof. dr. Alexander Sevrin (VUB)
Prof. dr. Nick Van Remortel (UAntwerpen)

The defense will take place on

Thursday, July 4, 2024 at 4.00 p.m. in auditorium I.0.01

The defense can also be followed through a live stream:
https://us06web.zoom.us/j/89644832487?pwd=3rJkHx6e0gaWbGEGjdEEFIM32Y1XRJ.1

Members of the jury

Prof. dr. Michael Tytgat (VUB, chair)
Prof. dr. Sara Bals (UAntwerpen, secretary)
Prof. dr. Nelson Christensen (Université Côte d'Azur, France)
Prof. dr. Irina Dvorkin (Sorbonne Université, France)

Curriculum vitae

Kevin obtained his master's degree in Physics and Astronomy in 2020 at the VUB. Subsequently, he started a joint PhD between the VUB and the UAntwerpen. Over the course of his PhD, he published eight peer-reviewed articles in international journals. He also had the opportunity to present his work at several conferences throughout the world. Additionally, during his PhD, Kevin also taught the exercise sessions for a first-year physics course and supervised several bachelor and master students with their thesis research and writing.

Abstract of the PhD research

Albert Einstein formulated his theory of general relativity and predicted the existence of ripples of spacetime: gravitational waves (GWs). The first detection of GWs by the LIGO-Virgo-KAGRA (LVK) collaborations happened almost a century later and started a new era: GW astronomy. In addition to the ninety GW detections in the third LVK observing run, a large number of weaker sources are expected to contribute to an overall gravitational-wave background (GWB). Depending on the source, astrophysical or cosmological contributions can be distinguished. The former receives contributions such as the merger of binary black holes (BBHs) or supernova explosions, whereas the latter would come from cosmological processes that happened during the history of our Universe. Due to the many sources contributing to the background, its detection would reveal a wealth of information and represents the holy grail of GW astronomy. Furthermore, the cosmological background forms a unique way to probe the high energy scales involved in these processes, usually unattainable by detectors on Earth. This thesis considers both contributions to the GWB, both from a data analysis and modelling perspective, with emphasis on bridging the two.

For the astrophysical background, the development of a data analysis technique to reduce the time until the detection of such a background formed an important part of this work. The GWB from BBHs can be distinguished from other contributions in the LVK detectors through its intermittent nature. As the duration of the signals is shorter than the time in between signals, this background appears popcorn-like. A new data analysis method that targets this intermittency is developed and the improvements in time-to-detection compared to other searches are illustrated. In addition, the implications of the detection of this background for the formation and evolution of BBHs are explored, by using data from the LVK detectors.

Within the possible cosmological sources, attention is paid to first order phase transitions. As the temperature of the Universe decreases, these phase transitions can take place and generate a GWB. The study of these phase transitions and the resulting GWB, forms the target of the last part of this work. The goal is to understand the detectability of such signals and to set constraints on models given available GW data from the LVK detectors. This illustrates how particle physics and GW physics can go together to unlock the information contained in the background.