SCIENCES & BIOENGINEERING SCIENCES

The Research Group

High-Energy Physics

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

Paul Coppin

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:
Investigation of the precursor phase of gamma-ray bursts through gamma-ray and high-energy neutrino observations

Promotor:
Prof. dr. Nick van Eijndhoven (VUB)
Co-promotor:
Prof. dr. Krijn De Vries (VUB)

The defense will take place on
Friday, April 22, 2022 at 16h in auditorium D.2.01

The defense can also be followed through a live stream. Please contact paul.coppin@vub.be for more information.

Members of the jury

Prof. dr. Jorgen D'Hondt (VUB, chair)
Prof. dr. Sophie de Buyl (VUB, secretary)
Prof. dr. Frank De Proft (VUB)
Prof. dr. Kumiko Kotera (Institut d'Astrophysique de Paris - VUB)
Prof. dr. Markus Ahlers (Niels Bohr Institute)
Prof. dr. Simona Toscana (ULB)
Prof. dr. Gwenhaël de Wasseige (Université Catholique Louvain la Neuve)

Curriculum vitae

During his physics education, Paul focused his studies on the astroparticle and computational aspects of physics. His master thesis research involved a study of the future IceCube-Gen2 neutrino observatory and was awarded by the IUAP Robert Brout prize and the BPS best master thesis prize. After obtaining his degree at the VUB in 2017, he started his PhD on an experimental study of gamma-ray bursts. During this time, he served as the teaching assistant for two physics courses, and supervised the theses of several bachelor and master students. His research involves data driven analyses that involve observations from neutrino and gamma-ray observatories. The results from these studies have been presented at international conferences and published in peer reviewed journals.

Abstract of the PhD research

Just over 50 years ago, satellite observations led to the discovery of a new, previously unknown type of astrophysical phenomena. These events correspond to extremely bright bursts of highly energetic light and were accordingly named gamma-ray bursts (GRBs). Following their discovery, it was shown that GRBs originate from cosmological distances, implying that they are one of the most energetic and extreme phenomena in our Universe. Two processes have been shown to produce GRBs. Certain massive stars can induce a burst when they have used up all their nuclear fuel, triggering a cataclysmic explosion. Alternatively, a GRB can also occur when a compact remnant of a burned-up star collides with another such remnant. Both types of sources induce an explosion in which material is ejected with extremely high energies. Conventional models suggest that shock wave and collision processes in these ejecta lead to the production of gamma rays and other high-energy particles, including neutrinos.

A highly interesting feature is that a subset of bursts exhibit precursor emission, i.e. a dim gamma-ray flash 10-100 seconds prior to the main outburst. Several physical mechanisms have been proposed to explain these early gamma-ray signals, but currently there is still no consensus as to their origin. What many candidate models do have in common is that the physical conditions during the precursor phase could lead to a significant flux of high-energy neutrinos. This argument motivates a coincidence study between GRB precursors and high-energy neutrinos. Observing such a precursor neutrino signal would reveal important aspects of the physics of GRBs and prove that GRBs are sources of both high-energy neutrinos and cosmic rays.

The goal of this research is to obtain a better understanding of GRB physics through a study of the precursor phase. To this end, two types of analyses have been performed. First, an analysis was applied to gamma-ray light curves recorded by the Fermi satellite from NASA. New techniques were developed to enable a reliable identification of precursor emission. Over 2,000 GRBs were analysed, leading to an extensive catalogue of GRB precursors and enabling novel features about these events to be uncovered. In the second part of our research, data from the IceCube neutrino observatory was used to search for neutrino signals from GRB precursors. Two likelihood analyses were performed. One search determined if a neutrino excess is observed coincident with the identified gamma-ray precursor flashes. A second, more generic analysis was also performed to search for neutrinos that arrive prior to the main gamma-ray outburst. Given the significant improvement in sensitivity compared to previous analyses, this study for the first time allowed to confirm or fully rule out certain model predictions.