SCIENCES & BIOENGINEERING SCIENCES

The Research Group
High Energy Physics

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

Yarno Merckx

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

From Cosmic Crashes to High-Energy Neutrinos

Supervisor:
Prof. dr. Krijn de Vries (VUB)
Co-supervisor:
Prof. dr. Nick van Eijndhoven (VUB)

The defence will take place on

Monday, September 15 2025 at 5 p.m.

VUB Etterbeek campus, Pleinlaan 2, Elsene in auditorium I.0.01.

The defence can also be followed through a live stream.

Members of the jury

Prof. dr. Stijn Buitink (VUB, chair)
Prof. dr. Alberto Mariotti (VUB)
Prof. dr. Vincent Ginnis (VUB)
Prof. dr. Simona Toscano (ULB)
Prof. dr. Juliana Stachurska (UGent)

Curriculum vitae

In 2021, Yarno earned an MSc in Physics and Astronomy from VUB and was awarded a four-year PhD fellowship by the FWO. His research focused on high-energy neutrino emission from luminous and ultraluminous infrared galaxies in close collaboration with NASA's GOALS project. This work led to a peer-reviewed publication and several presentations, including a presentation at the International Cosmic Ray Conference, the premier conference in astroparticle physics. In parallel, he analyzed data from the IceCube Neutrino Observatory at the South Pole, uncovering promising results related to this source class.

Beyond research, Yarno contributed to teaching in (astro)particle physics, supervised theses, engaged in outreach, organized seminars, and represented doctoral students on various councils.

Abstract of the PhD research

The IceCube Neutrino Observatory, a cubic-kilometer particle detector embedded deep in Antarctic ice, is designed to detect high-energy neutrinos in the giga- to peta-electronvolt range. Unlike photons or charged particles, neutrinos are electrically neutral and interact only weakly with matter, enabling them to travel vast cosmic distances without absorption or deflection. Neutrinos thus provide direct insight into the most extreme astrophysical environments. In 2013, IceCube discovered a diffuse flux of astrophysical neutrinos, but the specific sources producing these particles remain unknown. This thesis investigates luminous and ultraluminous infrared galaxies (LIRGs and ULIRGs; U/LIRGs) as potential high-energy neutrino sources. These galaxies, with infrared luminosities exceeding ten times the Milky Way's total output, are powered by intense star formation and, in some cases, accreting supermassive black holes. Their compact, dust-enshrouded regions provide favorable conditions for cosmic-ray acceleration and neutrino production through interactions with dense gas and radiation.

The research focuses on a nearby sample of U/LIRGs identified in NASA's Great Observatories All-sky LIRG Survey (GOALS). In collaboration with the GOALS team, a starburst-driven neutrino emission model was developed and applied to multiwavelength data. This analysis produced the first systematic estimate of per-source detectability of neutrinos from a large U/LIRG sample. The results show that individual galaxies in this population are beyond IceCube's current sensitivity but could be within reach of future facilities such as IceCube-Gen2.To explore their broader impact, the model was extended to incorporate the evolution of U/LIRGs throughout cosmic history using analytic methods. These results suggest that such galaxies could significantly contribute to the diffuse astrophysical neutrino flux detected by IceCube. As a first step toward refining these predictions, the model was incorporated into large-scale hydrodynamical simulations of galaxy formation in the Universe, linking galaxy properties more directly with neutrino emission.

Complementing the theoretical work, a search for neutrino emission from 113 GOALS galaxies was conducted using 13 years of IceCube data from the Northern Hemisphere. While no statistically significant signal was found, the results align with model predictions of low per-source fluxes. Notably, a tentative excess was observed from the direction of NGC 7469, warranting further study with future data.