VUB SCIENCES & BIOENGINEERING SCIENCES

The Research Group
High-Energy Physics

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

Maria Knysh

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

Probing Black Hole Physics with Semiclassical Microstates

Supervisor:
Prof. dr. Ben Craps (VUB)

The defence will take place on
Tuesday, June 30, 2026 at 4 p.m.

VUB Etterbeek campus, Pleinlaan 2, Elsene,
In auditorium I.0.02

The defence can be followed through a live stream: PhD Defence | Meeting-Join | Microsoft Teams

Members of the jury

Prof. dr. Alexander Sevrin (VUB, chair)
Prof. dr. Christoph Uhlemann (VUB)
Prof. dr. Steven Lowette (VUB)
Prof. dr. Chiara Toldo (ULB)
Prof. dr. Javier M. Magán (University of Barcelona & Centro Atómico de Bariloche, ES & AR)

Curriculum vitae

Maria Knysh is a PhD researcher in high-energy theoretical physics at the Vrije Universiteit Brussel. After completing her undergraduate and Master's studies at KU Leuven (2015-2020), she moved to Brussels for her PhD.

Her research explores what black holes can teach us about quantum gravity. In particular, she studies how information is stored, hidden, and recovered in black-hole systems, and how concepts such as entropy, complexity, and quantum chaos can shed light on the quantum structure of gravity.

Abstract of the PhD research

Black holes are far more than fascinating astrophysical objects. They are powerful theoretical laboratories that allow us to gain insight into quantum gravity. Classically, black holes are special geometries that satisfy Einstein's equations and possess a surface of no return, the horizon. Beyond this classical picture, however, black holes behave as thermodynamic objects with well-defined temperature and entropy. This thermodynamic behaviour strongly hints at an underlying microscopic structure that arises when quantum effects are taken into account. Yet, classical gravity completely hides this internal quantum architecture behind the event horizon. This creates a fundamental challenge in modern physics: how does this hidden quantum structure give rise to the classical geometry of spacetime?

This thesis addresses this puzzle through the construction of infinitely many semiclassical microstates that are exact solutions to Einstein's equations. Crucially, these geometries are indistinguishable from a given black hole outside the horizon but differ in their interiors, which contain heavy matter shells. Importantly, not all these geometries are independent. Their overlap is computed using the Euclidean gravity path integral. Equipped with the correct counting prescription that accounts for these overlaps, they span a finite-dimensional Hilbert space whose dimension matches the Bekenstein-Hawking entropy of the black hole.

Within this framework, this thesis presents three main contributions. First, we address the longstanding factorization problem of the Hilbert space for double-sided black holes in Anti-de Sitter space. Relying purely on gravitational methods, we demonstrate that under certain conditions, the Hilbert space indeed factorizes into left and right components to leading order in the semiclassical limit. Second, we extend the microstate construction to describe black holes with infalling matter shells. We demonstrate that the dimension of the Hilbert space in this case is determined by the horizon area of the black hole before the shell falls in. Finally, we embed this semiclassical microstate framework in a doubly holographic setting and verify that the same counting prescription correctly reproduces the exact quantum corrections to black hole entropy by computing the dimension spanned by these microstates.