VUB SCIENCES & BIOENGINEERING SCIENCES

The Research Group
Theoretical High Energy Physics

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

Philip Hacker

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

Complexity, chaos and black hole microstates

Promotors:
Prof. dr. Ben Craps

The defense will take place on
Thursday, June 29, 2023 at 9 am in auditorium D.0.08

Members of the jury

Prof. dr. Alexander Sevrin (VUB, chair)
Prof. dr. Ann Dooms (VUB, secretary)
Prof. dr. Michael Tytgat (VUB)
Prof. dr. Michal Heller (UGent)
Prof. dr. Nele Callebaut (University of Cologne)

Curriculum vitae

Philip Hacker obtained a master's degree in physics at the Technical University in Vienna in 2019 before he went on to pursue a PhD in the theoretical high energy physics research group at the VUB. During his PhD, he studied quantum evolution complexity in different quantum systems as well as probes of chaos in extremal black holes and corresponding microstate geometries. His research resulted in two peer reviewed publications and one preprint. He co-supervised bachelor and master students and taught exercises for several courses.

Abstract of the PhD research

The black hole information paradox, the question whether information is preserved in the presence of black holes, is one of the main puzzles of theoretical physics today. Resolving it means to solve a quantum mechanical problem in a strong gravitational field which is vital to the understanding of quantum gravity. In addition, it is known that black holes carry a large amount of information, but it is not understood how this information is carried by the black hole. In other words, what are the microstates that make up the black hole?

It is widely believed that the answers to these questions can be found within the framework of the holographic principle, relating a gravitational theory to a theory without gravity in one dimension less. Recently, new entries to the holographic dictionary relating the quantum computational complexity of a region in the boundary theory to various quantities in the gravity theory have been proposed. While quantum computational complexity can be defined in a rather elegant way, its computation is very hard for systems involving more than a few degrees of freedom. We have therefore developed an upper bound that we have been able to determine numerically for a range of quantum mechanical systems. Furthermore, we have demonstrated that this bound can distinguish reliably between chaotic and integrable behavior in these systems.

The second question raised in the first paragraph has been answered for specific black holes in the context of string theory, where explicit microstates have been identified more than twenty years ago. The so-constructed microstates are called fuzzballs. Later, it was shown that some of these microstates correspond to smooth classical geometries without any horizon, so-called microstate geometries. On the other hand, more recent developments using holography have connected probes of quantum chaos in the boundary theory, in particular the out-of-time-order correlator (OTOC), to scattering problems in the gravity theory. In black holes, the scattering happens close to the horizon. We have computed the OTOC in the black hole corresponding to a well-studied microstate geometry, the (1, 0, n) superstrata, and we have studied how the OTOC is modified in the horizonless microstate geometry.