SCIENCES & BIOENGINEERING SCIENCES

The Research Group

**Theoretical Particle Physics**

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

# Pierluigi Niro

to obtain the degree of Doctor of Sciences

Joint PhD with Université Libre de Bruxelles

Title of the PhD thesis:

**Strong coupling in 2+1 dimensions from dualities, holography, and large N**

Promotors:
**Prof. dr. Ben Craps**
**Prof. dr. Alexandre Sevrin**
**Prof. dr. Riccardo Argurio**

The defense will take place on

**Tuesday, July 13, 2021 at 16h00**

The defense can be followed through a live stream. Contact Pierluigi.Niro@vub.ac.be for more information.

### Members of the jury

Prof. dr. Andrés Collinucci (ULB, Chair)
Prof. dr. Alberto Mariotti (VUB, Secretary)
Prof. dr. Shira Chapman
(Ben Gurion University of the Negev, Israel)
Prof. dr. Andreas Karch
(University of Texas, USA)

### Curriculum vitae

Pierluigi Niro obtained his MSc. degree in Physics with distinction from the University of Florence in 2017. He started his joint PhD program in Theoretical High Energy Physics at ULB and VUB in 2017. His research was funded by an aspirant fellowship of the FRS-FNRS and dealt with the study of quantum field theories at strong coupling in three and four spacetime dimensions. During his PhD he has published 4 peer-reviewed papers in international journals and 1 preprint. He participated at several conferences and schools, and gave 5 oral presentations. He has been teaching assistant for two courses in the MSc. program at ULB.

### Abstract of the PhD research


Quantum Field Theory (QFT) is the most successful framework for the description of a wide range of phenomena, from particle and nuclear physics to condensed matter and statistical mechanics.

A physical system typically experiences regimes where the coupling constants are not small and the usual perturbative approach is not reliable, the most famous example being the low-energy regime of QCD, the theory of strong nuclear interactions. This is also relevant for those condensed matter systems (which are usually defined on the lattice), whose long-distance behavior is well described by a continuous QFT at its (strongly coupled) critical point.

The goal of the original research presented in the thesis is to study the strong coupling regime of QFTs with different methods, making concrete predictions about the phase structure and the dynamics of these theories, and on their observables. The focus is on (gauge) field theories in three spacetime dimensions, which are an interesting laboratory to understand the properties of strong coupling in setups that are usually simpler than in the more familiar case of gauge theories in four dimensions. Importantly, topological effects play a relevant role in three dimensions, thanks to the presence of the so-called Chern-Simons term.

The web of three-dimensional infrared dualities, the large N expansion, and the holographic correspondence between QFT and gravity are the main tools which we use to investigate the strongly coupled regimes of 3d QFTs.

In particular, we present a coherent proposal for the low-energy behavior of some classes of gauge theories coupled to fermions and a topological term, making progress in understanding their conjectured dual theories. Moreover, we show how the information about the strongly-coupled dynamics of QCD in three and four dimensions can be captured by dual gravitational setups, arising from string theory constructions. Finally, we prove new strong/weak dualities at large N, by considering the coupling between two QFTs defined in different spacetime dimensions.