Research Projects & Background

My research background has centered on quantum field theory since my undergraduate studies. There I worked on Algebraic Quantum Field Theory (AQFT) and the Unruh/Hawking effect where, in my dissertation thesis, I used the formalism of AQFT to describe a measurement scheme due to Fewster and Verch —that generalizes the quantum information theory measurements— of a quantum relativistic system. There, I first showed a rigorous proof of the Unruh-Hawking effect and then showed the importance of incorporating «covariant» measurement schemes on quantum information theory and proposed a measurement scheme for a Unruh-de Witt detector where I computed explicitly the scheme and showed it matches with the perturbative Unruh-de Witt system computation.

After finishing my bachelor I moved to Trieste, Italy, to perform a postgraduate diploma in theoretical high energy physics. There, I had the privilege of learning from professor Agnese Bissi expertise on Conformal Field Theories (CFTs) and bootstrap on a 3 months final project. Supervised by Professor Bissi, I studied holographic boundary CFTs (BCFTs), a type of CFTs with extended operators —boundary— that can be studied using tools from a gravitational theory due to the AdS/CFT duality. There, by analyzing the structure of Witten diagrams —a perturbative tool for computing correlation function in the gravitational theory— in the presence of boundaries, I computed the conformal block decomposition in both the bulk and boundary channels and examined the behavior of contact terms in these expansions.

This exploration led me to study of how double-trace operators play a crucial role in ensuring consistency with crossing symmetry in defect setups i.e. on ensuring the consistency of their underlaying CFT. These findings demonstrated how extended operators (boundaries) impose additional restrictions on the «space of holographic CFTs», a topic that I find particularly intriguing and would like to explore further in the future.

Later on, I moved to Paris, France, to start my master studies at the École Normale Supérieure where I joined Professors Miguel Paulos and Yifei He's bootstrap group. My interest in RG flows and their interplay with extended operators led me to start a project on studying monotonic quantities along RG flows —such as the central charge c for 2d CFTs and it's higher-dimensional analogs e.g. a-anomalies—. In this work, I unwrapped the Komargodsky's and collaborators' ideas on defect RG flows, particularly focusing on the behavior of the « g-function », a monotonic quantity analogous to the central charge c to line defects. In this project I conducted calculations in both free theories and the O(N) model, showing how the energy-momentum tensor arises on the bulk and on the line defects and, the behavior of the g-function showing screening of line defects.

These results have shown new insights into the interplay between RG flows and extended objects, including how line defects can exhibit phases of matter —due to the famous area and perimeter law's— and, it gives explicit constraints on the operator product expansions that are allowed to have line defects. We planned to continue exploring this function for defects that cannot be induced by an RG flow triggered by localizing bulk degrees of freedom on a line. One instance of these realizations are the monodromy defects and, more excitingly, the recent proposal of N. Drukker and collaborator's on «Transdimensional defects» have hinted novel RG triggering mechanisms for surface defects. I am extremely eager to explore this direction.

In addition to analytical tools to study CFTs, I have also been interested in numerical/computational projects. In a machine learning project, I developed a transformer-based model to convert QED Feynman diagrams into amplitudes. That is, the program receives any QED process in the form of a Feynman diagram, up to 1 loop, and returns the corresponding amplitude squared symbolic expression —with a 98% success rate— in terms of the scattering parameters, e.g. mass of the particles, Mandelstam variables, etc. We have ideas to extend this model in order to generate solutions to crossing symmetry in CFTs, i.e. to find allowed CFTs or, at the very least, to give constraints for operators/spectra of the theory where an upcoming paper of Miguel Paulos tells how in 1D a large amount of crossing symmetry solutions can be found to train the program. These ideas can be combined with Emilio Trevisani's ideas of « Uplifting » 1d-CFTs to 3d (Parisi-Sourlas) CFTs which, in turn, will allow us to use this information to train a program that « solves » 3d CFTs where they might even give insights to their (if exists) holographic CFTs.

Additionally, on of the most exciting project I have been working on is due to my first year master internship with Professor Yifei He. We continued exploring her « Gauge Theory Bootstrap » program for the Pion-Pion scattering. Indeed, by combining UV information from perturbative QCD with IR constraints from Chiral Perturbation Theory in the pion-pion scattering, we were able to bootstrap an S-matrix that captures all known poles of the theory, providing a novel non-perturbative result for solving QCD. In this project I have contributed by implementing a efficient tool for this bootstrap reducing the execution time from roughly half an hour to a minute where the full S-Matrix is found –in contrast with the interpolation point implemented in the original work, where few points of the $S-$matrix where found. This not only allow us to have a better grasp of the information our theory provides at all energies but to efficiently « experiment » into the parameters of the gauge theory.

We are currently investigating how explicit forms of the S-Matrix provide deeper insights into the structure of gauge theories. Additionally, we are thinking about the incorporation of non-invertible symmetries on our bootstrap as recent work has attracted much interest in this topic. Beyond these projects, I am also delighted with the high mathematical flavor that high energy physics has adopted and built from geometry and topology, and therefore, I am excited to incorporate these tools in my future projects where already from the 90's work in rational CFTs shed light on the importance of algebraic and categorical tools such as characteristic classes and fusion rules for describing operators and symmetries.