P.h.D. in Physics and Nanoscience XXXVI Cycle
First Year Report

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15/09/2021

Research Activity

During the first year of my P.h.D, I worked in the context of Quantum Field Theories (QFT) with boundary, extending and generalizing the work of my Master Thesis [1]. The study of boundaries is fundamental for overcoming idealized theories, for which the so called *boundary effects* are usually concealed at infinity. The introduction of boundaries has been particularly fruitful in the study of Topological Field Theories (TFT) [2], for example in the abelian 3D Chern-Simons (CS) theory, where the most surprising physical success comes from the discovery of local edge Degrees Of Freedom (DOF), since TFT are characterized by the absence of physical local observables *i.e.* they have vanishing Hamiltonian and energy-momentum tensor. The presence of the boundary gives this non-physical theory a surprisingly rich physical content: the recovered DOF describe the edge states of the Fractional Quantum Hall Effect [3, 4]. Something similar happens for the 3D and 4D BF theories with boundary, describing Topological Insulators (TI) [5]. On a completely different side, an example of non-TFT with boundary is given by the AdS/CFT correspondence [6], where gravity with an AdS black hole metric in 5D has a Conformal Field Theory (CFT) as 4D holographic counterpart and relevant physical applications are found in Condensed Matter Theory [7].

My main activity, concerning QFT with boundary, in this first year, has been focused to investigate what are the effects of considering the higher-dimensional bulk theory in curved spacetime, instead of flat Minkowski (or Euclidean) well known cases. The aim was to detect if and how the bulk metric played a role in the boundary theory. The first case I studied was the abelian CS theory, which, as mentioned above, is a TFT and, as such, has no metric dependence in the bulk (*i.e.* no energy-momentum tensor). That is not necessarily true for the induced boundary theory: in the same way as local edge DOF arise from the introduction of the boundary, a metric dependence could emerge and therefore cannot be excluded. If it does appear, which observables does it affect? The analysis showed that the boundary (Kaç-Moody) algebraic structure is unaffected by the curvature of spacetime (as one would expect from a CFT), but most relevant is the fact that the induced metric does play a role in the 2D boundary theory, which still describes edge states of FQHE, in one of the fundamental observables: the chiral velocity v. This velocity, usually assumed as constant, can now acquire an implicit spacetime dependence through the induced metric determinant and, being v a phenomenological parameter, this opens at the possibility of observing an accelerated chiral velocity: $v(\gamma(t,x))$.
Driven by this result, the case I considered in the next step was the abelian 3D BF model with boundary, in curved spacetime. As anticipated, it is another, example of TFT, known to describe (at least in flat spacetime) the surface states of TI when in presence of a boundary. Preliminary calculations seem to produce analogous results as the CS case (induced metric determinant involved in the observables of the boundary theory), but there is still work that needs to be done.
In parallel with all that, and in particular in the first half of the year, I deepened my knowledge of the AdS/CFT correspondence, in view of a future possible tentative of comparing its "dictionary" with the techniques and results I typically use: they both are approaches that make (physical) sense when considering theories with boundary, but can they coincide?

Courses Attended

- *Fisica Statistica* (48h Master Course) - Exam Passed
  Dott. A.Amoretti
- *From the Thermodynamics to the statistical Mechanics of Black Holes*
  Prof. S.Giusto
- *Introduction to AdS/CFT and its Applications* - Exam Passed
  Dott. A.Amoretti
- *Mathematical Aspects of QFT*
  Prof. N.Pinamonti and M.Benini
- *Theoretical Physics*
  Prof. G.Ridolfi

Schools/Workshops/Conferences/Awards

- 23rd Symposium on the interplay between Quantum Matter and Gravity (online)
  29-30th June 2021
- Milla Baldo Ceolin award
  8th July 2021
- GGI Workshop: Topological properties of gauge theories and their applications to high-energy and condensed-matter physics
  6-19th September 2021
- GGI Conference: "Women in Theoretical Physics" - Premio Nazionale in memoria della Prof.ssa "Milla Baldo Ceolin"
  21st September 2021
- MITP Virtual Workshop: Quantum Field Theory at the Boundary (poster expected)
  27-30th September 2021

Publications

- *Notes from the bulk: metric dependence of the edge states of Chern-Simons theory*
  Authors: E.Bertolini, G.Gambuti, N.Maggiore
  (submitted for publication)

References

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[3] E. Fradkin and A. Lopez, Phys. Rev. B **44**, 5246-5261 (1991) doi:10.1103/PhysRevB.44.5246

[4] S. C. Zhang, Int. J. Mod. Phys. B **6**, 25-58 (1992) doi:10.1142/S0217979292000037

[5] G. Y. Cho and J. E. Moore, Annals Phys. **326**, 1515-1535 (2011) doi:10.1016/j.aop.2010.12.011

[6] J. M. Maldacena, Int. J. Theor. Phys. **38**, 1113-1133 (1999) doi:10.1023/A:1026654312961

[7] S. Sachdev, Lect. Notes Phys. **828**, 273-311 (2011) doi:10.1007/978-3-642-04864-7_9