Annual PhD report - First year

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XXXVIII cycle

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1 Research activity

I am a theoretical physicist, working on statistical mechanics. My research interests are on one-dimensional quantum integrable models and, in particular, on topologically frustrated quantum spin chains.
Geometrical frustration is a situation in which the geometry of our system does not allow the spins to orient themselves in a way to simultaneously minimize all the local interactions. While extensive (*i.e.* scaling with the system's size) frustration has already been largely studied (leading to new peculiar and exotic physics), theorists began only recently to interest on frustration as induced by a particular choice of boundary conditions imposed on antiferromagnetic quantum spin chains, namely periodic boundary conditions with an odd number of sites. They were named *Frustrated Boundary Conditions* (FBC) and they are special because it has been shown that frustrated quantum spin chains show different behaviors from their non-frustrated counterparts, even in the thermodynamic limit. In particular, it has been proved, through non-perturbative analytical exact calculations and numerical analysis, that FBC can destroy the local order, modify the nature of quantum phase transitions (QPTs) and induce new boundary (*i.e.* non-extensive) QPTs. These facts underline the incompleteness of Landau theory (according to which boundary conditions can only matter in finite systems) in describing this class of many-body quantum systems. The research activity of my first year has been mainly focused on the study of the effects of topological frustration on one of the most famous one-dimensional integrable models, the quantum XY chain in a transverse magnetic field. Its zero temperature phase diagram is very peculiar and completely different from its (well-known) unfrustrated counterpart, indeed, for instance, topological frustration closes the mass gap and creates a region of the parameter space characterized by a continuous cross-over between mutually orthogonal ground states, thus simulating the behavior of models with continuous symmetries. In particular, we discovered that FBC can induce new boundary QPTs (both of the first and of the second order) which are absent without frustration and our analytical results were also confirmed by a numerical analysis performed by Prof. Fabio Cavaliere. Furthermore, to the best of our knowledge, we found the first case of second order QPT characterized by a dispersion relation which is neither relativistic nor Galilean but quartic. This work, that will be published soon, was done in collaboration with Prof. Fabio Franchini from Ruđer Bošković Institute (Zagreb).
Furthermore, with the goal of understanding the topological nature of these phenomena in mind, I spent some time of this year in studying how topological terms appear in low-energy effective field theories for quantum spin chains, focusing in particular on the Heisenberg chain.
To conclude, this year I acquired by myself several notions of Field Theory and Integrability that I had no chance to cover during courses or schools, but which will be essential for my future research activity.

2 Courses and exams

I attended the following courses:

- *Statistical Physics of Out of Equilibrium Systems*, Prof. N. Magnoli (Master Degree course).
- *Conformal Field Theories*, Prof. N. Magnoli (PhD course).

- *Introduction to AdS/CFT and its applications*, Dr. A. Amoretti (PhD course).
- *Non Abelian Gauge Theories*, Prof. N. Maggiore (PhD course).

I gave these exams:

- Conformal Field Theories: I focused on *Conformal Field Theory in Two Dimensions*.
- Non Abelian Gauge Theories: I presented a seminar on *Descent equations and Chern-Simons forms*.
- GGI school SFT 2023: I presented a seminar on *Strongly interacting one-dimensional systems under confinement: exact solutions*, based on the course held by Prof. A. Minguzzi.

3 Conferences and schools

- GGI school *SFT 2023 - Lectures on Statistical Field Theories* (38 hours) at Galileo Galilei Institute for Theoretical Physics (Arcetri, Firenze), 6-17 Febuary 2023.