Ph.D. student: Paolo Meda
Supervisor: Pierantonio Zanghì
Co-supervisor: Nicola Pinamonti

RESEARCH ACTIVITY

My research activity is focused on the analysis of quantum theories on flat and curved spacetimes, in particular I am interested in the study of gravitational effects in quantum theories at fundamental level. I am member of the INFN experiment Bell, Group IV, area of Mathematical Physics.

A first approximation for a quantum field theory on curved spacetimes is the "semi-classical" approach, which consists in describing the back-reaction of a quantum matter field propagating over a fixed curved spacetime. In this semi-classical formulation, the Einstein tensor of the classical metric is equated to the expectation value of the quantum stress-energy tensor in physically relevant states. This general approach can be applied to many different subjects: for instance, to cosmological models, in order to compute quantum corrections to the Friedmann equation which appear to be of relevance in the early universe (some models of inflation, like Starobinsky one, are based on this view). Moreover, a semiclassical analysis of backreaction effects on a black hole geometry predicts non-classical effects like Hawking radiation and black hole evaporation. Hence, in this approximation, it is possible to describe some aspects of the black hole physics and/or black hole thermodynamics.

Two topics have been treated during the last year: the Operator Product Expansion (OPE) and the Semiclassical Einstein Equation (SEE).

1. The OPE is a mathematical tool in quantum field theory which allows to expand a two-point function into expectation values of local fields, evaluated in a fixed point of the spacetime. Regarding this topic, I have discussed the mathematical and physical conditions which ensure the reconstruction of the two-point function of a physically meaningful state from the OPE. In particular, I have seen that this reconstruction is not always possible, unless certain analytic conditions are satisfied by the state, both on flat and curved spacetimes. Moreover, I also proved that, in case of the Minkowski vacuum, fundamental properties like the positivity of the energy and the translational invariance symmetry of the flat spacetime guarantee the uniqueness of the reconstruction. That problem is now investigated in the general case, without imposing directly any analyticity condition for the two-point function but deriving it from more fundamental physical properties.
2. The SEE describes the backreaction of the quantum matter on the classical spacetime geometry. Unfortunately, at this date, a general proof of the existence and uniqueness of its solution is lacking and hence the physical analysis of its approximated solutions is not well under control.
   During the first year of the Ph.D. course, I considered the backreaction of a massive quantum scalar field on a cosmological spacetime. Together with H. Gottschalk and D. Siemssen from University of Wuppertal, we proved the existence and uniqueness of solutions of this system of equations in the case of generic coupling to the curvature (I spent some days, from July 21th to July 27th, at the University of Wuppertal for this collaboration). It is now meaningful to analyze the physical properties of the found solution which could be of relevance at the early stage of the Universe. We are currently preparing a draft containing the proof.

COURSES, EXAMS, SCHOOLS, WORKSHOPS

I have attended the following six courses:

- Introduction to AdS/CFT and its applications (A. Amoretti)
- Cosmologia (N. Maggiore)
- Renormalization group à la Wilson-Polchinski (C. Imbimbo)
- Complementi di Fisica Matematica (P. Martinetti).
  Link: https://unige.it/off.f/2018/ins/31414.html
- Mathematical Methods for Quantum Theories (C. Dappiaggi), a Ph.D. course from University of Pavia, about the following topics: Hyperbolic PDEs, black holes and linear stability of rotating black holes.

I gave the exams of the following courses in form of seminars (titles are quoted in parenthesis):

- Introduction to AdS/CFT and its applications ("The Holographic Renormalization")
- Cosmologia ("Basics of cosmological perturbation theory")
- Complementi di Fisica Matematica ("The surface gravity and black hole thermodynamics")
- Mathematical Methods for Quantum Theories ("An introduction to the Semiclassical Einstein Equation")

I joined the 43rd LQP workshop "Foundations and Constructive Aspects of QFT" in Florence at GGI, February 20th-22th (webpage: https://sites.google.com/view/43-lqp).

I attended the summer school "School on quantum foundations dedicated to Prof. Giancarlo Ghirardi"" at ICTP, June 19th-21th, about Collapse Models, Bohmian Mechanics and Shape Dynamics (webpage: http://www.fpqp.eu:8080/?q=schoolfoundations/2019).

PUBLISHED ARTICLES / CONFERENCES

No articles have been published this year.

I gave an oral talk, with a ppt presentation, during the summer school in Trieste:

Title: "Analytic conditions for the Operator Product Expansion"

Abstract:
A first approximation for a quantum field theory on curved spacetimes is the semi-classical formulation of gravity: the quantum theory is applied to the matter source (the stress-energy tensor) and is encoded in the expectation value on a quantum correlation function, while the metric of the spacetime plays the role of a fixed background. In this framework, I will present some results concerning the expansion of a physical two-point correlation function in terms expectation values of local fields at the coinciding point, the so-called Operator Product Expansion (OPE for short), and, in particular, I will discuss the mathematical and physical conditions that insures the reconstruction of an unknown two-point function starting from its OPE.