Matteo Cardi

Second Year PhD Report

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Research Activity (under the supervision of Pierantonio Zanghì)

During my second year, I worked together with P. Zanghì and P. Solinas on the Unruh effect.
According to quantum field theory, given a quantum field in its vacuum state in Minkowski spacetime, a linearly accelerated observer predicts such vacuum state to be a thermal state at a temperature T_U, proportional to the acceleration of the observer, called "Unruh temperature". To measure this temperature, DeWitt proposed in 1983 an interaction between a scalar field (in its vacuum state) and a fermion field (in its one-particle state), which acts as a microscopic detector serving as a thermometer, referred to as the Unruh-DeWitt detector.
Our work focused on the theoretical aspects of measuring the Unruh temperature using the aforementioned detector, aiming to explore its behaviour in realistic experimental settings, highlighting the relevant scales at which the Unruh effect may be observable.
In particular, we studied the case in which the detector is delocalized in an extended region of space. We showed the limit extension for which the detector is described by a thermal state and we found the associated temperature.
However, detecting the standard Unruh effect is a significant technical challenge due to the extremely high acceleration required. This raises the question of whether an analogue of the Unruh effect might exist for non-linear accelerations (e.g. for rotations). Currently, there is no formal result confirming or refuting the existence of a generalized Unruh effect. My recent research activity has been focused on the proof of existence or non-existence of such an effect.

Courses

I attended the following courses:
- Advanced statistics for data analysis (F. Badaracco, F. Di Bello, F. Parodi),
- Introduction to the Foundations of Quantum Mechanics and Applications (P. Zanghì, P. Solinas),
- Black hole's thermodynamics (S. Giusto).

I took the following exam:
- Non-abelian Gauge Theories (N. Maggiore).

Teaching activities

- Tutor of the theoretical group during high school's stages,
- Tutor of the course "Fisica Generale" for Electrical Engineering and Chemical and Process Engineering.

Publication

- *On the Measurement of the Unruh Effect Through Extended Quantum Thermometers*, Authors: P. Solinas, M. Cardi, P. Zanghì

Abstract: The Unruh effect, predicting a thermal reservoir for accelerating systems, calls for a more refined understanding of measurement processes involving quantum systems as thermometers. Conventional models fail to account for the inherent spatial extent of the thermometer, neglecting the complexities associated with accelerated extended quantum systems. Our work builds upon the seminal work of Bell, Hughes, and Leinaas. We propose a refined thermometer model incorporating a spin-1/2 particle where the spin acts as a temperature indicator. This refined model demonstrates the ability to effectively measure the temperature under specific, realistic conditions, providing a unique value that essentially averages the local Unruh temperatures throughout the extended quantum system acting as the thermometer.