Matteo Cardi

First Year PhD Report

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Research Activity (under the supervision of Pierantonio Zanghì)

My research activity is focused, on one hand, on the study of gravity using the formalism of geometrodynamics, on the other hand, on the interplay between gravity and quantum mechanics.
Research on Gravity: General Relativity can be formulated as a dynamical theory with the space $\mathcal{S}(\Sigma)$ of riemannian 3-geometries over Σ as its configuration space. This formulation goes under the name of *geometrodynamics*. Formally, $\mathcal{S}(\Sigma)$ can be seen as the quotient of the space of riemannian 3-metrics Riem(Σ) over the diffeomorphism group D(Σ). The resulting dynamical system can be regarded as a constrained system, where the presence of constraints is due to the request on the geometry to be diffeomorphism invariant.
In this framework, we are interested in the study of an even more constrained system, namely, the *conformal geometrodynamics*, defined by the quotient of $\mathcal{S}(\Sigma)$ by the conformal group. The goal of this research is to study the modification of the usual constraints of geometrodynamics, look for solutions and analyze the connection between General Relativity and conformal geometrodynamics.
Research on Quantum Mechanics and Gravity interplay: 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, an accelerated observer sees such vacuum state as a thermal state at the Unruh temperature T_U, proportional to the acceleration of the observer. In order to measure such temperature, in 1983, DeWitt proposed an interaction between a scalar field (in its vacuum state) and a fermion field (in its one-particle state) representing a (microscopic) thermometer, called the *Unruh-DeWitt detector*.
We focused on theoretical aspects of the measurement process of the Unruh temperature when such a detector is still microscopic, but delocalized in space. In particular we showed how the outcome depends on the state of the particle, giving rise to a *measured* Unruh temperature, which, in general, is different from the theoretical one.
Furthermore, we studied the role of the tunnel effect in such a system, showing whether or not the measured Unruh temperature changes and, if it does, how.

Courses

I attended the following courses:
- Fisica delle strutture cosmiche (M. Raveri, 6CFU),
- Non-Abelian Gauge Theories (N. Maggiore, 3CFU),
- AdS/CFT (A. Amoretti, 3CFU).

Conferences

I attended the following conference:
- "Quantum Effects on Gravitational Fields" in Leipzig, Germany from August 28 to September 01.

Publication (in preparation)

○ *Unruh effect for extended thermometers*, Authors: P. Solinas, M. Cardi, P. Zanghì
Abstract: We study the Unruh effect for a quantum particle delocalized in space with different branches of the wave function having different proper accelerations. As a microscopic model, we consider a spin 1/2 fermion confined in a double-well potential and use the spin degrees of freedom as a quantum thermometer, i.e., as an Unruh-DeWitt detector. This allows us to keep track of the different approximations used, and the relativistic effect and gives clear physical meaning to the measurement process. We consider the two cases in which tunneling is or is not allowed between the confining wells. In the first case, we find the wave function branches locally thermalized to the Unruh temperature associated with the well acceleration. When tunneling is allowed between the wells, this is most likely to become the dominant effect and the stationary state is changed. The wave function is localized in the lowest energy well and it thermalizes with the associated Unruh temperature.