Manuele Filaci, PhD student – 3rd year activity

Advisors:
Carla Biggio, Pierre Martinetti

Attended schools:
SIGRAV International School 2020 Gravity, Vietri sul Mare (Italy):

- Geometrical and field theoretical manifestations of General Relativity and its generalizations (S. Capozziello)
- Testing Gravity (P. Pani)
- Cosmology beyond General Relativity (T. Baker)
- Cosmological Perturbation Theory and Primordial Gravitational Waves (S. Matarrese)

Seminars and talks:
Video-Poster – Let's Twist! Beyond the Standard Model Physics from Twisted Non-Commutative Geometry (Galileo Galilei Institute, Firenze, Italy, Online Event)

Research subjects and research activity:
Non-commutative geometry:
Non-commutative spaces are a generalization of manifolds. Every manifold is associated with an algebra, the algebra of smooth functions on the manifold. It can be shown that there is a one-to-one correspondence between manifolds and their associated algebra, so that if one has complete information of the algebra, he or she can completely reconstruct the manifold that algebra originated from. If one replaces the usual algebra of smooth functions, which is of course commutative, with another, non-commutative algebra, the space that can be constructed from that algebra will be a non-commutative space.
Non-commutative spaces are the natural framework to place quantum field theories in. In fact, it can be shown that the gauge symmetries in non-commutative spaces are just other geometrical symmetries, like translation invariance or rotation invariance. For this reason, one of the main features of non-commutative geometry is that it describes all interactions as gravity, i.e. as geometrical deformations of the underlying space, therefore giving a unified
description of all possible interactions. Another important feature of non-commutative geometry is that it unifies the description of all bosons as connections, and this includes not only the vector bosons, but also all the scalar fields.
I focused my research on twisted spectral triples, which are a kind of non-commutative spaces that get twisted in some mathematical sense. In practice, one replaces the usual commutator with a slightly modified one. The twist has a very interesting consequence: even if one starts with an Euclidean non-commutative space, after the twist, the action and all the physics that originates from it are all Lorentz-invariant. This might be a hint of why there is exactly one time dimension and why it behaves differently from the other spatial dimensions.
My research activity was the following.
Study of three different twists and their corresponding extensions of the Standard Model (SM): twist-by-grading, and another two non-canonical twists.
Computation of the fluctuation of the Dirac operator in the three models.
Identification of the physical gauge fields in the three models.
Computation of the unimodularity condition in the three models.
Computation of the full fermionic part of the action for all three models.
Computation of the gauge transformations of the fields (both fermionic and bosonic) in the three models.

Study of the strange gauge behaviour of the scalar fields for one particular twist, and consequent redefinition of the physical scalar degrees of freedom.
Study of possible extensions to the twisted case of the definition of the spectral action.
Study of techniques to compute the spectral action in the twisted (Lorentzian) background.
Proof of the mutual independence of the physical scalar fields in the three models.
Study of the real algebra of a generic twisted spectral triple.
Further study on the physical meaning of the transition from Euclidean to Lorentzian signature in the inner product.

Publications:

- Global Bounds on the Type III Seesaw, *C. Biggio, E. Fernandez-Martinez, M. Filaci, J. Hernandez-Garcia, J. Lopez-Pavon. (2020) Journal of High Energy Physics. 2020. 10.1007/JHEP05(2020)022.*
- Actions for twisted spectral triple and the transition from the Euclidean to the Lorentzian, *A. Devastato, M. Filaci, P Martinetti, D. Singh. (2020). International Journal of Geometric Methods in Modern Physics. 10.1142/S0219887820300019.*
- Twisted Standard Model in noncommutative geometry I: the field content, *Manuele Filaci, Pierre Martinetti, Simone Pesco. arXiv:2008.01629.*