# Manuele Filaci, PhD student – 2nd year activity

**Supervisor:**
Carla Biggio

**Attended courses and given exams:**
Complementi di Fisica Matematica (Pierre Martinetti) (exam given)

**Seminars and talks:**
Seminar on type III see-saw at DIFI (Università degli Studi di Genova)
Talk + poster on type III see-saw at Invisibles19 Workshop (Valencia)

**Research subjects and research activity:**

Neutrino physics:

I focused my studies on the type III see-saw models. See-saw models are models that try to explain why neutrino have masses, and why they are so small compared to other fermions. The idea is to give neutrinos an additional, huge Majorana mass, in addition to the usual Dirac mass, so that the physical masses, after diagonalization of the mass matrix, are very tiny for the left-handed neutrinos, and very big for the extra particles added to the Standard Model in order to introduce the Majorana mass term.
There are many ways to introduce this Majorana mass, and one of them is by adding fermion triplets to the Standard Model. This kind of models are the Type III see-saw models.
**My research activity was the following.** Study of 3 different models of type III see-saw: general case (where an arbitrary number of triplets is added to the Standard Model), 3 triplets case (both for Normal Hierarchy (NH) and Inverted Hierarchy (IH) of light neutrino masses) and 2 triplets case (again, both for NH and IH). Update of the constraints on the parameters of the models using the recently improved bounds on many observables (in particular, from nu-fit, PDG and Planck). Study of the constraints induced by the hypothesis of an approximate lepton number symmetry on the mass matrices for the 3 triplets and 2 triplets models. In-depth study of the extra constraint on the Majorana phase in the 2 triplets scenario. In the last two weeks, I also started to study the present LHC bounds on the 2 triplets model.

Non-commutative geometry (in collaboration with Pierre Martinetti):

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.** Computation of the fluctuation of the free Dirac operator. Computation of the fluctuation of the Yukawa part of the finite Dirac operator. Computation of the Majorana part of the finite Dirac operator and computation of the full fluctuated Dirac operator. Computation of the eigenstates of the R operator, which implements the twist on the algebra of the triple. Partial computation of the fermionic action of the resulting theory. Physical interpretation of the transition from Euclidean to Lorentzian signature in the inner product.