# WORKSHOP ON NONCOMMUTATIVE GEOMETRY, ANALYSIS, AND TOPOLOGICAL INSULATORS

UNIVERSITEIT LEIDEN, FEBRUARY 3-4, 2020

## Programme

All talks will take place on the first floor of Snellius. Exact room number in the table below.

**Monday 3 February.**

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| 9:30 - 10:30 | 405 | Carlo Beenakker, Instituut-Lorentz<br>*Random-matrix theory of topological states of matter* |
| 10:30 -11:00 | 405 | Coffee/tea break |
| 11:00 - 12:00 | 405 | Constanza Rojas-Molina, Université de Cergy-Pontoise<br>*Random Schrödinger operators and Anderson localization in aperiodic media.* |
| 12:00 - 13:30 | 174 | Lunch break |
| 13:30 - 14:30 | 174 | Giovanna Marcelli, Universität Tübingen<br>*A new approach to transport coefficients in the quantum (spin) Hall effect.* |
| 14:30 - 15:30 | 174 | Vadim Cheianov, Instituut Lorentz<br>*Non-Abelian fractional quantum Hall states, classification and experimental detection.* |
| 15:30 - 16:00 | 174 | Coffee/tea break |
| 16:00 - 17:00 | 174 | Jean Bellissard, Georgia Tech and WWU Münster<br>*Topological Insulators: Physics and Disorder.* |
| 17:00 - | | Drinks in the FooBar |
| 19:00 | | Social Dinner |

**Tuesday 4 February.**

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| 9:30 - 10:30 | 408 | Domenico Monaco, Università di Roma La Sapienza<br>*Parseval frames of exponentially localized magnetic Wannier functions* |
| 10:30 - 11:00 | 408 | Coffee/tea break |
| 11:00 - 12:00 | 408 | Koenraad Schalm, Instituut-Lorentz<br>*Noncommutative geometry in string theory* |
| 12:00 - 13:00 | 408 | Lunch break |
| 13:00 - 14:00 | 174 | Hessel B. Posthuma, Universiteit van Amsterdam<br>*On the K-theoretic classification of crystalline topological insulators* |
| 14:00 - 15:00 | 174 | Chris Bourne, Tohoku University<br>*Spectral flow and topological phases* |

**Carlo Beenakker, Instituut-Lorentz**
**Random-matrix theory of topological states of matter.** The theory of random matrices goes back to the 1960's and has found applications in many branches of physics. In condensed matter physics, random-matrix theory can describe the universal properties of disordered metals and superconductors, dependent only on the presence or absence of fundamental symmetries in 10 symmetry classes (the socalled "ten-fold way"). It was recently discovered that 5 out of these 10 symmetry classes have a topological invariant, which identifies distinct states of matter. Some of these topological superconductors and insulators have been realized in the laboratory. In this seminar we will discuss how random-matrix theory can be extended to account for topological properties.

**Constanza Rojas-Molina, Université de Cergy-Pontoise**
**Random Schrödinger operators and Anderson localization in aperiodic media.** In this talk we review old and new results on the phenomenon of dynamical localization arising in disordered aperiodic media, as for example, in disordered quasicrystals. We then discuss how random SchrÃ¶dinger operators appear as auxiliary models in the study of wave propagation in purely aperiodic systems, and its consequences on the transport and spectral properties of such materials.

**Giovanna Marcelli, Universität Tübingen**
**A new approach to transport coefficients in the quantum (spin) Hall effect.** We derive a formula for the linear response coefficients in quantum charge and spin transport, within the one-particle approximation, for a general class of gapped periodic Hamiltonian operators, for both discrete and continuum models. The starting point of our derivation is not the standard Kubo formula, based on time-dependent perturbation theory and a formal exchange of limits, but an alternative way that relies on the explicit construction of non-equilibrium almost-stationary states. While the definition of the charge current operator is well known, an intense debate about the correct expression of spin current operator has not reached a common consensus yet. Our rigorous analysis sheds some light on the physical relevance of the different definitions of the spin current operator. This talk is based on joint work with D. Monaco (La Sapienza, Rome), G. Panati (La Sapienza, Rome), and S. Teufel (Universität Tübingen).

**Vadim Cheinaov, Instituut-Lorentz**
**Non-Abelian fractional quantum Hall states classification and experimental detection.** In this talk I will discuss an effective field theory approach to the classification of strongly correlated topologically ordered states associated with the fractional quantum Hall effects. I shall then proceed to the experimental evidence for the existence of non-Abelian states and the difficulties with its interpretation.

**Jean Bellissard, Georgia Tech and WWU Münster**
**Topological Insulators: Physics and Disorder.** Topological insulators will be described together with their physical properties. The main experiments will be presented. Then the elementary steps in constructing the formalism in absence of disorder will be described. A list of recent results will be given. In the last part, the description of a case in which it is possible to prove the stability of the topological invariants under a disorder will be presented even if localized states fill the gap at the Fermi level.

**Domenico Monaco, Università di Roma La Sapienza**
**Parseval frames of exponentially localized magnetic Wannier functions.** Wannier functions are a spanning set of localized states for the occupied energy bands of a crystalline insulator, composed of all the lattice translations of a finite number of functions. In 2-dimensions and in presence of an external uniform magnetic field with rational flux through the unit cell of the crystal, it is well known that the topology of the space of occupied states obstructs the existence of an orthonormal set of localized Wannier functions: the topological obstruction

is quantified by the Chern number. I will show how, by removing the orthonormality constraint, one can still construct a spanning set of localized Wannier functions in the form of a Parseval frame even in the topologically obstructed case. Moreover, the frame is made of the "minimal number" of functions, namely m+1 localized orbitals together with their (magnetic) translations, if m is the number of occupied energy bands. The construction can be extended perturbatively in the external magnetic field to yield Parseval frames of localized Wannier functions also for (some) irrational values of the magnetic flux per unit cell. At the end of the talk, I will hint to possible generalizations in the direction of noncommutative geometry.

**Koenraad Schalm, Instituut-Lorentz**
**Noncommutative geometry in string theory.**

**Hessel B. Posthuma, Universiteit Amsterdam**
**On the K-theoretic classification of crystalline topological insulators.** In this talk I will sketch, following Freed and Moore, how an exotic version of twisted equivariant K-theory classifies topological phases of free fermions in condensed matter physics. This version of K-theory turns out to be mathematically interesting in its own right. After that I will illustrate the theory with some computations in some examples with crystal symmetries, based on joint work with de Boer, Kruthoff and Stehouwer.

**Chris Bourne, Tohoku University**
**Spectral flow and topological phases.** We will first review spectral flow and its application to bulk and boundary properties of the quantum Hall effect. We will then introduce the so-called KO-valued spectral flow, defined in joint work with Alan Carey, Matthias Lesch and Adam Rennie, and how it can be used to recover the classification of topological insulators and superconductors by Kennedy and Zirnbauer. Time permitting, we will then present recent joint work with Johannes Kellendonk and Adam Rennie, which uses the Cayley transform on Hilbert C*-modules to generalise many of these ideas.