

UNIVERSITY OF MILAN

Public selection for recruiting No. 1 tenure track researcher(s) (RTT) for competition sector 01/A4 - Mathematical Physics, (scientific-disciplinary sector) at the Department of Mathematics ``Federigo Enriques'', (announcement published in Official Gazette No. 21 of 12/03/2024) - Competition code 5512

## Alexander Bols

### CURRICULUM VITAE

(N.B. CV MUST BE OF UP TO 30 PAGES AND INCLUDE THE DETAILS CANDIDATES CONSIDER USEFUL FOR THE ASSESSMENT.

ALL THE TITLES INSERTED BELOW ARE JUST EXAMPLES THAT CAN BE REPLACED, CHANGED OR COMPLETED)

#### PERSONAL DATA (DO NOT INCLUDE YOUR PERSONAL ADDRESS AND LANDLINE OR MOBILE PHONE NUMBER)

SURNAME	BOLS
NAME	ALEXANDER
DATE OF BIRTH	
Citizenship	Belgian

#### QUALIFICATIONS

##### DEGREE

(Specify full degree name, University, date, etc.)

degree name : Master of Physics (Master of Science)  
result : Magna cum laude  
university : KULeuven  
date : 02/07/2015

##### DOCTORAL DEGREE OR EQUIVALENT QUALIFICATION EARNED IN ITALY OR ABROAD / MEDICAL SPECIALISATION DIPLOMA OR EQUIVALENT QUALIFICATION, FOR THE RELEVANT SECTORS, EARNED IN ITALY OR ABROAD

(Specify qualification full name, institution, date, etc.)

degree name : Doctor of Science (PhD)  
university : KULeuven  
date : 16/05/2019

##### RESEARCH CONTRACTS, RESEARCH FELLOWSHIP CONTRACTS, POSTDOCTORAL SCHOLARSHIPS OR SIMILAR CONTRACTS

(Specify, for each contract, university/institution, starting and termination date, etc.)

1. postdoctoral position at Copenhagen university  
start : 01/09/2019      end : 31/08/2022

2. postdoctoral position at California Institute of Technology (Caltech)  
start : 07/09/2022      end : 30/06/2023
3. postdoctoral position at ETH Zurich  
start : 01/09/2023      end : ongoing

#### TEACHING ACTIVITIES AT ITALIAN OR FOREIGN UNIVERSITIES

*(Specify academic year, university, degree course, number of hours etc.)*

As course responsible

- Advanced Mathematical Physics at Copenhagen university, spring 2020
- Advanced Mathematical Physics at Copenhagen university, spring 2022

As teaching assistant

- Thermodynamics at KULeuven
- General Physics I at KULeuven
- General Physics II at KULeuven
- Capita Selecta in Theoretical Physics at KULeuven
- Mathematical Physics at KULeuven
- Complex Functions at KULeuven

As project supervisor

- Bachelor project ``Stability of the solar system" at KULeuven
- Bachelor project ``Percolation theory and phase transitions" at KULeuven
- Bachelor project ``the eigenstate thermalization hypothesis" at KULeuven
- Master thesis ``Absolute continuity of the edge spectrum of disordered Landau Hamiltonians from index theory" at Copenhagen university

#### ATTESTED TRAINING OR RESEARCH ACTIVITIES AT QUALIFIED ITALIAN OR FOREIGN INSTITUTIONS

*(Specify academic year, institution, course, period, etc.)*

- Teacher assistant training  
As part of the doctoral training programme at the Arenberg Docotoral School (KULeuven)  
academic year 2015-2016
- Course for teaching assistants  
at Copenhagen university  
academic year 2019-2020

#### SPEAKING AT NATIONAL AND INTERNATIONAL CONFERENCES AND CONVENTIONS

*(Specify conference/convention title, date, etc.)*

Invited speaker at school ``Arizona School of Analysis and Mathematical Physics" in Tucson, Arizona.  
(05/03/2018 - 09/03-2018)

Invited speaker at workshop ``Topological Phases of Interacting Quantum Systems" in Oaxaca, Mexico. (02/06/2019 - 07/06/2019)

speaker at conference ``ICMP Young Researcher Symposium" in Geneva, Switzerland. (02/08/2021 - 07/08-2021)

Invited speaker at conference ``Quantissima in the Serenissima IV" in Venice, Italy. (22/08/2022 - 26/08/2022)

Invited speaker at conference ``Solid Math 2022" in Trieste, Italy. (06/09/2022 - 09/09/2022)

speaker at workshop ``TOPO23" in Tuebingen, Germany. (27/11/2023 - 08/12/2023)

## SCIENTIFIC PRODUCTION

### SCIENTIFIC PUBLICATIONS

(For each publication, specify the following: authors' names, full title, publisher, date and place of publication, ISBN/ISSN/DOI or equivalent code)

1. A. Bols, W. De roeck, ``Asymptotic Localization in the Bose-Hubbard Model", Journal of Mathematical Physics, 2018, doi:10.1063/1.5022757
2. S. Bachmann, A. Bols, W. De Roeck, M. Fraas, ``Quantization of conductance in gapped interacting systems", Annales Henri Poincare, 2018, doi:10.1007/s00023-018-0651-0
3. A. Bols, ``Quantization of Charge Transport in Gapped Ground States" PhD Thesis, 2019, Leuven. <https://lirias.kuleuven.be/retrieve/538314>
4. S. Bachmann, A. Bols, W. De Roeck, M. Fraas, ``A Many-Body Index for Quantum Charge Transport", Communications in Mathematical Physics, 2019, doi:10.1007/s00220-019-03537-x
5. S. Bachmann, A. Bols, W. De Roeck, M. Fraas, ``Note on linear response for interacting Hall insulators", Analytic Trends in Mathematical Physics, 2020, doi:10.1090/conm/741/14918
6. S. Bachmann, A. Bols, W. De Roeck, M. Fraas, ``Many-body Fredholm index for ground-state spaces and Abelian anyons", Physical Review B, 2020, doi:10.1103/PhysRevB.101.085138
7. S. Bachmann, A. Bols, W. De Roeck, M. Fraas, ``Rational indices for quantum ground state sectors", Journal of Mathematical Physics, 2021, doi:10.1063/5.0021511
8. A. Bols, A. Werner, ``Absolutely continuous Edge Spectrum of Hall Insulators on the Lattice", Annales Henri Poincare, 2021, doi:10.1007/s00023-021-01097-2
9. A. Bols, J. Schenker, J. Shapiro, ``Fredholm Homotopies for Strongly-Disordered 2D Insulators", Communications in Mathematical Physics, 2022, doi:10.1007/s00220-022-04511-w
10. A. Bols, B. Kjaer, A. Moon, ``The double semion state in infinite volume", accepted for publication in Annales Henri Poincare, 2024

### PREPRINTS

1. A. Bols, ``Classification of equivariant quasi-local automorphisms on quantum chains" ([arXiv:2106.02145](https://arxiv.org/abs/2106.02145))
2. A. Bols, C. Cedzich, ``Absolutely continuous edge spectrum of topological insulators with an odd time-reversal symmetry" ([arXiv:2203.05474](https://arxiv.org/abs/2203.05474))
3. A. Bols, S. Vadnerkar, ``Classification of the anyon sectors of Kitaev's quantum double model" ([arXiv:2310.19661](https://arxiv.org/abs/2310.19661))

## RESEARCH INTERESTS

The general theme of my research is to understand topological phases of interacting matter, especially in the context of microscopic models on the lattice.

### Current projects

*Many-Body Kane-Mele index* : Two dimensional free-fermion insulators with an odd time reversal come in two topological phases distinguished by the  $\mathbb{Z}_2$ -valued Kane-Mele index. Together with Sven Bachmann and M. Rahnema I am working on a proof that the Kane-Mele phase persists when interactions are allowed. The proof makes rigorous the intuition that in the non-trivial Kane-Mele phase, a background  $\pi$ -flux binds a Kramers pair.

*Kitaev's quantum double models in infinite volume* : Some ten years ago P. Naaijken and others started translating the DHR formalism of algebraic quantum field theory to develop a rigorous theory of topological order for two dimensional lattice spin systems. The most mature version of this construction was published last year by Y. Ogata. This formalism assigns to any gapped ground state a braided  $\mathcal{C}^*$ -tensor category, whose irreducible objects are the anyon types supported by the ground state. The formalism was successfully applied to abelian quantum double models, but dealing with non-abelian models remained out of reach for eight years, until S. Vadnerkar and I managed to classify the anyons of these models in the context of the DHR formalism. We are currently working together with P. Naaijken and M. Hamdan to also establish the fusion and braiding properties of the non-abelian quantum double models in the DHR formalism.

*Gauging SPT phases* : A d-dimensional quantum system with a global symmetry  $G$  may be gauged. It turns out that gapped ground states in two dimensions with a global symmetry  $G$  come in different "symmetry protected topological (SPT) phases", indexed by the third group cohomology of  $G$  with coefficients in  $U(1)$ . It is conjectured that gauging such an SPT yields a topologically ordered state whose anyons are described by the Dijkgraaf-Witten theory corresponding to gauge group  $G$  and twisted by the group cohomology of the SPT state. Together with A. Moon and B. Kjaer I am working on a proof of this conjecture in the case  $G=\mathbb{Z}_2$ , using the rigorous formalism for topological order alluded to above.

### Planned projects

*Topological order in three dimensions* : Recent years have seen the appearance of many interesting three-dimensional models that are topologically ordered. These models have string-like excitations that may fuse and braid non-trivially with each other, much in the same way that the point-like anyons in two-dimensional topologically ordered materials do. A systematic understanding of such three-dimensional topological orders is mostly lacking. I aim to develop a formalism, similar to the DHR formalism alluded to above, to describe rigorously such three-dimensional topological orders.

*The Chiral central charge* : The biggest open problem in two-dimensional topological phases is understanding the so-called *Chiral central charge*. The intuition goes as follows. Consider a Hall insulator with an edge. Then there are gapless edge modes whose effective low energy description is given by a chiral CFT. Since the chirality of the CFT has nothing to do with the charge conservation symmetry (which is needed to define the Hall conductance, which is a well-understood topological invariant), this chirality of the edge CFT is believed to be robust under breaking the charge conservation symmetry of the Hall insulator. The fact that the edge theory is chiral is believed to indicate that this system is in a non-trivial topological phase, even if charge conservation is not imposed. Establishing the existence of such chiral phases is a more or less completely open problem. I intend to devote a significant amount of time to understanding these phases.

Date

05/04/24

Place

Zurich, Switzerland