ESI Erwin Schrödinger International Institute for Mathematical Physics

universität wien

Scientific Report for 2014

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Preface

The Institute and its Mission in 2014

The Erwin Schrödinger International Institute for Mathematical Physics (ESI) is committed to the promotion of scholarship in mathematics and physics. Outreach to aspects of other fields in which mathematics or physics play a central role is a natural part of the mission of the ESI. In the first years, its focus was on mathematical physics and mathematics. Since its origin in 1993, it has gained international reputation in these fields of research. Over the years, the thematic spectrum of its scientific activities was carefully extended, while maintaining its high scientific standards. Recently, the ESI has enlarged its fields of competence to include computational, experimental and theoretical aspects of mathematics and physics. This evolution is particularly well suited to the new ESI status.

In 2011, as a consequence of a political decision, the Erwin Schrödinger International Institute for Mathematical Physics was turned into a research centre within the University of Vienna. The institutional transition of the ESI from an independent research institute to a "Forschungsplattform" at the University of Vienna was a complicated process over the last years but is now finished. Supported by the international as well as the local community of scholars, the Institute has continued to function during the radical changes to its status and the ongoing construction work at its physical location in Vienna.

The Scientific Advisory Board of the ESI and the Kollegium of the ESI share the view that the following points are of crucial importance for the further development of the Institute:

(1) It is desirable to intensify the process of widening the scope of themes offered at the ESI. At the same time, it is important to maintain the specific profile and scientific standards of the ESI.

(2) It is vital for maintaining the ESI's influence that research groups of the University of Vienna continue to be strongly involved in the activities of ESI as they have been since the origin of the Institute – without intensive connections to scientists in the Vienna area, the ESI could not function at this high scientific level.

(3) All ESI activities continue to include strong educational components, from which students, graduate students, and young researchers at the University of Vienna profit greatly. Summer schools, instructional lectures and the lecture courses given by Senior Research Fellows at the ESI are an essential part of the activity of ESI.

However, currently the financial situation of the University of Vienna is unclear and thus so is the funding of the ESI beyond 2015 [the end of the current funding period]. The University will not have clarity on its budget for the years 2016 – 2018 before autumn 2015. Despite the difficulties this time shift brings to us and the proponents of thematic programmes at the

ESI in 2016, the members of the Kollegium of the ESI, together with its Scientific Advisory Board (SAB), decided to move forward by preparing a final agenda for the scientific activities at the ESI in 2016. The topics of the scientific activities for 2016 will range from computational aspects in solid state physics and numerical aspects of nonlinear flows over pure mathematics to combinatorial aspects in theoretical physics.[1]

Scientific Activities in 2014

In 2014 the Institute continued to pursue its mission in the following ways:

(a) primarily, by running four *thematic programmes*, selected about two years in advance on the basis of the advice of the international ESI Scientific Advisory Board;

(b) by organizing six additional *workshops* and one *summer school* at shorter notice; the latter one jointly with the European Mathematical Society (EMS) and the International Association of Mathematical Physics (IAMP);

(c) by a programme of *Senior Research Fellows* (SRF), who gave lecture courses at the ESI for graduate students and post-docs;

(d) by a programme of *Research in Teams*, which offered teams of 2 to 4 *Erwin Schrödinger Institute Scholars* the opportunity to work at the Institute for periods of 1 to 4 months;

(e) by inviting *individual scientists* who collaborated with members of the local scientific community.

Thematic Programmes, Workshops and Summer School

It was the Institute's foremost objective to advance scientific knowledge ranging over a broad band of fields and themes in mathematics and physics. Creating a space where fruitful collaborations and the exchange of ideas between scientists can unfold remains imperative to the mission of the ESI. The list of research areas in mathematics and physics covered by the scientific activities of the ESI in 2014 shows a remarkable variety: The following thematic programmes, supplemented by six additional workshops and a summer school, were in place

– *Modern Trends in Topological Quantum Field Theory*
  February 3 – March 28, 2014
  (org. by Jürgen Fuchs (Karlstad U), Ludmil Katzarkov (U Vienna), Nicolai Reshetikhin (UC Berkeley), Christoph Schweigert (U Hamburg)),

– *Combinatorics, Geometry and Physics*
  June 2 – July 31, 2014
  (org. by Abdelmalek Abdesselam (U of Virginia), Christian Krattenthaler (U Vienna), Adrian Tanasa (U Paris North), Fabien Vignes-Tourneret (CNRS - U Lyon 1)),

[1]For details see `http://www.esi.ac.at/news/thematic-programmes-at-the-esi-in-2016`

– *Topological Phases of Quantum Matter*
  August 4 – September 12, 2014
  (org. by Nicholas Read (Yale U), Jakob Yngvason (U Vienna), Martin Zirnbauer (U Cologne)),

– *Minimal Energy Point Sets, Lattices and Designs*
  September 29 – November 21, 2014
  (org. by Christine Bachoc (U Bordeaux), Peter Grabner (Graz U of Technology), Edward B. Saff (Vanderbilt U, Nashville), Achill Schürmann (U Rostock)).

In addition, the following summer school and workshops were organized at shorter notice:

– *ESI–EMS–IAMP Summer School on Mathematical Relativity: 99 Years of General Relativity,*
  July 28 – August 1, 2014
  (org.: Robert Beig (U Vienna), Piotr T. Chruściel (U Vienna), Mihalis Dafermos (U Princeton), Helmut Friedrich (AEI Golm), Gregory Galloway (U Miami), Richard M. Schoen (Stanford U)),

– *Time-frequency Analysis*
  January 13 – 17, 2014
  (org.: Hans G. Feichtinger (U Vienna), Karlheinz Gröchenig (U Vienna)),

– *4th Central European Relativity Seminar*
  February 27 – March 1, 2014
  (org.: Lars Andersson (AEI Golm), Robert Beig (U Vienna), Piotr Bizoń (Jagiellonian U, Cracow), Piotr T. Chruściel (U Vienna), Helmut Friedrich (AEI Golm)),

– *Geometry of Computation in Groups*
  March 31 – April 11, 2014
  (org.: Goulnara Arzhantseva (U Vienna), Olga Kharlampovich (Hunter College, New York), Alexei Miasnikov (Stevens Institute of Technology, Hoboken)),

– *Theoretical and Applied Computational Inverse Problems*,
  May 5 – 16, 2014
  (org.: Liliana Borcea (U of Michigan), Otmar Scherzer (U Vienna), John C. Schotland (U of Michigan)),

– *Algebraic Quantum Field Theory: Its Status and its Future*,
  May 19 – 23, 2014
  (org.: Romeo Brunetti (U Trento), Claudio Dappiaggi (U Pavia), Klaus Fredenhagen (U Hamburg), Jakob Yngvason (U Vienna)),

– *Scaling Limits and Effective Theories in Classical and Quantum Mechanics*,
  September 22 – 26, 2014
  (org.: Chiara Saffirio (U Bonn), Benjamin Schlein (U Bonn), Sergio Simonella (TU Munich), Jakob Yngvason (U Vienna)).

The pages of this report provide ample evidence of the high quality of the scientific programmes. In particular, the thematic programmes and the open approach to research they offer and encourage form a fundamental pillar of the work of the ESI. The Institute provides a place for focused collaborative research and aims to create a fertile ground for new ideas.

Senior Research Fellows Programme

As in previous years, within the *Senior Research Fellows* programme, the ESI offered lecture courses on an advanced graduate level.

In the fall term October 2013 – January 2014, Ludwik Dabrowski (SISSA, Trieste) gave a course on *Spinors: Classical and Quantum* where he discussed in detail the latest layer of Non-Commutative Geometry: Riemannian and Spin. It is encoded in the concept of a spectral triple and its main ingredient, the Dirac operator.

In March – May 2014, Jan Philip Solovej (U Copenhagen) gave a course on *Many-body Quantum Physics*, combined with a weekly problem session. These lectures dealt with the formalism and the concepts of many-body quantum mechanics, including thermodynamic stability, Bose condensation, superfluidity and superconductivity. The main methods discussed were second quantization, reduced density matrices, and Bogolubov transformations.

Research in Teams Programme

By January 1, 2012, the Erwin Schrödinger Institute had established the *Research in Teams Programme* as a new component in its spectrum of scientific activities. The programme provides an opportunity to work at the Institute in Vienna for periods of 1 to 4 months, in order to concentrate on new collaborative research in mathematics and mathematical physics. The interaction between the team members is a central component of this programme. The ESI received a large number of proposals. However, due to limited resources, the Kollegium could only accept three of these applications for the year 2014. Other teams are already accepted for the year 2015.

- L. Funar (U Grenoble), A. Papadopoulos (U Strasbourg), *Mapping Class Group Dynamics and Simplicial Complexes on Surfaces of Infinite Type*, January 6 – February 2, 2014
- A. Carey (ANU Australia), F. Gesztesy (U of Missouri), D. Potapov and F. Sukochev (UNSW Australia) *Scattering Theory and Non-commutative Analysis*, June 22 - July 22, 2014
- F. Kupka and H, Muthsam (U Vienna), A. Petrosyan (Russian Academy of Sciences), O. Pomazan (Nat. Research Nuclear U MEPhI, Moscow), *Multiscale Models of Magnetohydrodynamic (MHD) Turbulence in Solar Convection*, September 1 – October 8, 2014

Miscellaneous

Kollegium

The ESI is governed by a board, to be called “Kollegium”, of six scholars, necessarily faculty members of the University of Vienna. Their term of office is three years. These members of the board are appointed by the Rektor of the University after consultations with the Deans of the Faculty of Physics and the Faculty of Mathematics. On December 31, 2013, the first term of office of the Kollegium was completed. Since January 1, 2014, the Kollegium consists of G. Arzhantseva, P. Chrusciel, A. Constantin, Ch. Dellago, A. Hoang, J. Schwermer.

Scientific Advisory Board

The composition of the International Scientific Advisory Board of the ESI changed at the end of the year 2013. After two terms of office, John Cardy (U Oxford) left the Board. The Institute is extremely thankful to him for many years of valuable advice and support. Denis Bernard (ENS Paris), Christian Lubich (U Tübingen) and Catharina Stroppel (U Bonn) joined the Board on January 1, 2014, as new members.

Administration

There was no change in the administration of the ESI in 2014. In spite of the ongoing construction work at the ESI in 2014 the administrative staff - Alexandra Katzer, Maria Marouschek and Beatrix Wolf - continued to work with their customary efficiency towards our visitors, research fellows and scientific staff.

Walter Thirring

On August 18, 2014, Walter Thirring, Professor of Theoretical Physics at the University of Vienna since 1959, passed away. His contributions to Quantum Field Theory, Elementary Particle Physics, Statistical Physics and General Relativity made him one of the pioneers of modern Mathematical Physics. The years 1990–1993, preceding the foundation of the Erwin Schrödinger International Institute for Mathematical Physics, had been a time of intense preparations involving many mathematicians and physicists. Walter Thirring, together with Heide Narnhofer and Peter Michor, acting on behalf of the scientific community, played a decisive role in the foundational period of the ESI and beyond. The members of the Institute deeply mourn the death of Walter Thirring.

Joachim Schwermer April 12, 2015
Director
Erwin Schrödinger International Institute for Mathematical Physics

The ESI in 2014

Director of the Research Centre ESI at the University of Vienna: Joachim Schwermer.

Kollegium of the Research Centre ESI at the University of Vienna: Joachim Schwermer (ESI Director), Goulnara Arzhantseva (ESI Deputy Director), Christoph Dellago (ESI Deputy Director), Piotr T. Chruściel, Adrian Constantin, Andre Hoang.

Administration of the Research Centre ESI at the University of Vienna: Alexandra Katzer (Head of Administration), Maria Marouschek, Beatrix Wolf.

Computing and networking support of the Research Centre ESI at the University of Vienna: Sascha Biberhofer.

International Scientific Advisory Board in 2014:

Denis Bernard (ENS Paris)
Isabelle Gallagher (U Paris-Diderot)
Helge Holden (U Trondheim)
Daniel Huybrechts (U Bonn)
Horst Knörrer (ETH Zürich)
Christian Lubich (U Tübingen)
Vincent Rivasseau (U Paris-Sud)
Catharina Stroppel (U Bonn)

Budget and visitors: In 2014 the support of ESI from the Austrian Federal Ministry of Science, Research and Economy received via the University of Vienna was € 790 000. The total spending on scientific activities in the year 2014 was € 344 691 (ESI) plus € 164 173 (third party funds), in total € 508 864 and on administration, infrastructure, and reconstruction work € 391 302.

The number of scientists visiting the Erwin Schrödinger Institute in 2014 was 736, see pages 95–109.

ESI research documentation: Starting from January 2014, the ESI research outcome is tracked using the arXiv database and the published articles. The ESI website provides web links to these arXiv preprints and to the local ESI preprints collected until December 2013. It also contains the bibliographical data of the already published articles. Moreover, publications which appeared in 2014 but are related to past ESI activities, starting from 2011, have been tracked as well in order to provide a long-term evidence of the ESI research outcome success.

The total number of preprints and publications contributed to the ESI research documentation database in 2014 is 129 [related to the activities in 2014: 109, related to the activities in previous years: 20], see pages 87–94 for details.

The Foundation ESI
President: Klaus Schmidt
Honorary President: Walter Thirring who passed away on August 18, 2014

Scientific Reports

Main Research Programmes

Modern Trends in Topological Quantum Field Theory

Organizers: Jürgen Fuchs (Karlstad U), Ludmil Katzarkov (U of Vienna), Nicolai Reshetikhin (UC Berkeley), Christoph Schweigert (U Hamburg)

Dates: February 3 – March 28, 2014

Budget: ESI € 42 560,
European Science Foundation (ESF) research training network ITGP, Interactions of Low-Dimensional Topology and Geometry with Mathematical Physics (€ 6 400), Deutsche Forschungsgemeinschaft (DFG) network program nr. 594335, String Geometry (€ 4 000), Claussen-Simon-Stiftung Hamburg, the mentorship price for Christoph Schweigert (€ 8 173).

Report on the programme

Topological field theories in various dimensions have been actively studied for more than 25 years. They have turned out to constitute a surprisingly rich structure, with a very wide range of applications, both in physics and in mathematics.

The following recent developments have been central for the programme:

- Three-dimensional topological field theories have become an important tool for studying mapping class groups of Riemann surfaces and their representations.
- In many situations, structure on representation categories can be naturally explained by an underlying (extended) topological field theory. In this way, the structure of cobordism categories – and thus topology – elucidates algebraic structures. An example is the celebrated Radford S^4 theorem for modules over Hopf algebras. In a similar way, cobordisms based on categories with manifolds with boundaries and / or defects arising in topological field theories with defects and boundaries elucidate structures on module and bimodule categories over monoidal categories and thus "categorified representation theory".
- In extended topological field theories, higher codimension structures are taken into account by considering extended cobordism categories. Thereby higher categorical structures naturally arise, in particular $(\infty, 1)$-categories. They provide the natural setting for the proof of the cobordism hypothesis, which classifies all fully extended topological field theories. These higher categorical structures have created strong links between topological field theory on the one side and various fields of algebraic topology, including differential cohomology theories, on the other side.

- In their original formulation, combinatorial constructions of invariants of three-manifolds, like those of Turaev-Viro or Reshetikhin-Turaev, strongly rely on semisimple categories with suitable additional structure. Recently, triggered by progress both in representation theory and logarithmic conformal field theory, the construction of variants of topological field theories based on non-semisimple categories has made steady and, as the ESI programme has shown, impressive progress.

The programme has brought together leading experts from mathematics and mathematical physics. On the mathematical side, the meeting involved mathematicians working in algbraic topology, geometry, and representation theory. From the perspective of physics, the programme included participants with a background in string theory and in statistical mechanics.

As is common for meetings at the ESI, a strong focus was on informal discussions which initiate new or continue existing scientific collaborations.

Activities

The programme comprised the following research activities:

- Two one-week workshops, each with about 20 talks of 50 minutes.
- Two master classes, each consisting of three 90-minute lectures.
- A one-week meeting of the junior research network "String Geometry" (sponsored by the German Science Foundation).
- Eight individual 60-minute talks outside the workshop periods.

It may also be mentioned that the Steering Committee of the ESF research training network ITGP (Interactions of Low-Dimensional Topology and Geometry with Mathematical Physics), which includes two of the participants of the programme, held a meeting at the ESI during the period of the programme.

Altogether these activities were attended by about 74 participants (56 of which received financial support from the ESI). Of these, 55 gave a talk. The total duration of stay amounted to about 116 person-weeks.

The two **master classes** each consisted of three lectures of 90 minutes.

Azat Gainutdinov (Hamburg) lectured on *Tensor categories in logarithmic conformal field theories*. He described how tensor categories, and, in particular, non-semisimple ones, arise in two-dimensional conformal field theories. He also explained how quantum groups at roots of unity and associated non-semisimple tensor categories are related to representations of vertex algebras, and thereby their relevance for logarithmic conformal field theories.

Gregor Masbaum (Paris) gave lectures on *Integral TQFT and applications to quantum representations of mapping class groups*. He showed how the combinatorial construction of the SO(3)-TQFT based on skein theory (due to Blanchet-Habegger-Masbaum-Vogel) admits, for roots of unity of prime order, an integral refinement: The vector space of conformal blocks at given genus contains a natural mapping class group invariant full-rank lattice defined over a ring of algebraic integers. The presence of this lattice allows for new insights into the structure of mapping class groups.

The master classes were attended by 7 PhD students from abroad, coming from Denmark, France, Germany and Sweden, but also by senior scientists present at the ESI as well as by local junior and senior scientists.

The two **workshop periods** concentrated on two different types of problems:
Workshop 1: Extended topological field theories, higher structures, and differential cohomology theories.
This workshop also dealt with infinity categories, topological conformal field theory and its application to Gromov-Witten invariants, cobordism categories with additional structure and the quantization of classical TFTs using higher structures.
Workshop 2: Topological and conformal field theories involving non-semisimple monoidal categories.
Different algebraic structures, in particular Hopf algebras and vertex algebras, lead to representation categories that are monoidal. Recent developments presented during workshop 2 have revealed that non-semisimple categories arising from Hopf algebras and from vertex algebras in logarithmic conformal field theories are much more closely related than specialists in both fields had realized before. Moreover, they are surprisingly similar to non-semisimple monoidal categories used for the construction of renormalized quantum invariants of links and three-manifolds.

In addition, during the two workshops and the **individual talks**, connections were made with various other structures. Examples include on the physics side statistical mechanics for systems with boundaries and open string field theory, and in representation theory the theory of module categories over finite tensor categories and, more specifically, over fusion categories as well as the equivariantization of categories. Both workshops also had some talks devoted to classical topological field theories and their quantization.

A component that was unforeseen in the original planning of the programme was a meeting of the junior **research network "String Geometry"**, sponsored by the German Science Foundation DFG. This network focusses on higher categorical aspects of geometry. Since many network members participated in the first workshop, it was decided that the semestrial meeting of the network should take place in Vienna (and thus for the first time outside Germany). This component involved 9 talks exhibiting recent progress by the participants as well as intensive collaborative research.

Specific information on the programme

Aside from senior scientists (see below) totally 11 PhD students and 17 postdoctoral researchers participated in the various activities of the programme.
PhD students: Bjerre, Buchberger, Esgaard, Harpaz, Marzioni, Meinel, Nitikenko, Nuiten, Santharoubane, Scheimbauer, Völkl.
Postdocs: Carqueville, Chen, Gainutdinov, Janssens, Johnson-Freyd, Morton, Nikolaus, Pandit, Pennig, Schreiber, Spitzweck, Valentino, Vertman, Voigt, Wood, Wockel.

Scientific content

In the sequel, we list some results presented during the programme, grouping thematically related contributions.

Explicit constructions of topological field theories. Several talks were devoted to explicit constructions of topological field theories. Combinatorial methods continue to provide a rather explicit computational access to such theories. This was demonstrated by Dror Bar-Natan (Toronto) for the combinatorics of perturbative BF-theories in three dimensions. Azat Gainutdinov (Hamburg) used quantized versions of Schur-Weyl duality to investigate state sum models of spin type. Rinat Kashev (Geneva) presented a construction of a topological field theory with infinite-dimensional state spaces using the combinatorial framework of triangulated manifolds. Kazui Habiro (Kyoto) discussed recent developments on Kirby calculus, Thang Le (Atlanta) described the role of the Habiro ring, and Qingtao Chen (Trieste) explained congruent skein relations with a motivation to study the LMOV conjectures.

Cobordism categories with additional structure. Variants of topological field theories can be constructed on cobordisms involving manifolds with additional structure. Ingo Runkel (Hamburg) presented a combinatorial construction of spin topological field theories in two dimensions. A related construction of a state-sum model for surfaces with spin structures was presented by John Barrett (Nottingham). Alexis Virelizier (Lille) explained his construction (with Turaev) of three-dimensional homotopy TFTs. Chris Schommer-Pries (Bonn) reported how finite tensor categories give rise to fully local partially defined thee-dimensional topological field theories, generalizing the case of (spherical) fusion categories for which the TFTs are fully defined. Additional structure on cobordisms then translate into additional structure on these categories.

Mapping class groups. The vector spaces assigned to surfaces by a three-dimensional TFT carry a representation of the relevant mapping class group. Jørgen Andersen (Aarhus) explained how such representations obtained via geometric quantization generalize from Reshetikhin-Turaev models based on the compact group $\mathrm{SU}(n)$ to the complex group $\mathrm{SL}(n,\mathbb{C})$. Joost Slingerland (Maynooth) discussed local representations of the loop braid group. Such representations arise in discrete gauge theories, e.g. those relevant for the toric code. Gregor Masbaum (Paris) used methods from integral topological field theories to investigate abstract group theoretical properties of mapping class groups.

Classical field theory. Classical topological field theory remains an active area with many open questions. Conversely, topological field theories shed a light on the mathematical structure of classical field theories, whereby they e.g. provide one possible mathematical perspective on partial differential equations. Thomas Strobl (Lyon) discussed the Dirac sigma model as a joint generalization of Poisson sigma models and gauged WZW models. Here Lie algebroid structures arise. Homotopy Frobenius structures appear in the generalization of AKSZ TFTs presented by Theo Johnson-Freyd (Berkeley). Operadic methods also played an important role in the relations between the Grothendieck-Teichmüller group and polyvector fields that was explained by Sergei Merkulov (Stockholm). Generalized Chern-Simons invariants constructed from L_∞-algebras were also central in the contribution by Andrey Lazarev (Lancaster).

Quantization. In a semiclassical approach to quantum field theory, determinants of Laplacians figure prominently. Gluing relations in topological field theories raise the question about gluing formulas for determinants, which was the topic of the contribution by Boris Vertman (Bonn). A much more direct approach is possible for topological field theories based on finite groups, so-called Dijkgraaf-Witten theories. Jeffrey Morton (Hamburg) presented a general construction of such extended TFTs, based on suitable linearization functors. An advanced general scheme for formalizing quantization via pull-push in twisted generalized cohomology was presented by Joost Nuiten and Urs Schreiber (Nijmegen).

Differential cohomology and gerbes. Topological field theories in three dimensions are closely related to conformal field theories in two dimensions. The latter typically have topological terms in their actions, which are naturally understood by differential cohomology theories and their geometric realizations, gerbes, and higher versions of gerbes. Thomas Schick (Göttingen) discussed geometric models for higher twisted K-theory, including a proposal for the notion of a homotopy bundle gerbe. Alan Carey (Canberra) presented a different geometric approach, based on Baum-Douglas geometric cycles. Mahmoud Zeinalian (Brookville) constructed a model of differential K-theory and its S^1-iteration maps that is based on a geometrically defined spectrum. Ulrike Tillmann (Oxford) introduced commutative K-theory, thereby obtaining new generalized cohomology theories. Ulrich Bunke and Thomas Nikolaus (Regensburg) explained how differential cohomology can be presented by a sheaf of spectra on manifolds, allowing for a discussion of twisted differential cohomology for an arbitrary multiplicative differential cohomology theory. Christian Becker (Potsdam) introduced two different notions of relative differential cohomology, and presented long exact sequences and fibre integration for both of them.

Fusion categories and their module categories. Fusion categories are the simplest possible input for the construction of a fully extended topological field theories in three dimensions. Much of their structure theory still remains to be unraveled. Scott Morrison (Canberra) reviewed existing classification results. Sonia Natale (Córdoba, Argentina) presented classification results on weakly group-theoretical braided fusion categories. Sebastian Burciu (Bucharest) reported on new results on the Grothendieck groups of equivariant fusion categories. Module categories over fusion categories appear in particular in the description of surface defects of three-dimensional TFTs. Gregor Schaumann (Bonn) presented a categorified version of $*$-modules for module categories, which is closely linked to Frobenius structures on algebras of internal Homs.

Defects in topological field theories. Defects of various codimension play an increasing role in the study and in applications of quantum field theories. Surface defects in three-dimensional topological field theories appear e.g. in the construction of quantum codes and in state sum models of condensed matter systems. Catherine Meusburger (Erlangen) presented a detailed analysis of dualities at various categorical levels for such defects. Alessandro Valentino discussed surface defects and boundary conditions of three-dimensional TFTs of Reshetikhin-Turaev type; these involve an obstruction taking values in the Witt group of modular tensor categories. Nils Carqueville (Stony Brook/Vienna) explained how to employ defects in two-dimensional field theories to produce equivalences of matrix factorizations. Kevin Walker (Santa Barbara) showed that three-dimensional defects in four-dimensional topological field theories (capturing e.g. the anomaly of three-dimensional Reshetikhin-Turaev type TFTs) allow one to understand the modularization procedure of Bruguières and Müger geometrically.

Non-semisimple categories, logarithmic conformal field theory. In their original formulation, combinatorial constructions of three-manifold invariants strongly rely on *semisimple* categories with suitable additional structure. More recently, insight both from mathematics as

well as from physics (as explained in the contribution by Jesper Jacobsen (Paris) on geometrical critical phenomena) have led to look for suitable categories that are no longer semisimple, but still allow one to construct at least substantial aspects of a three-dimensional TFT. Such categories have been much better understood by representation theorists recently: Drazen Adamovic (Zagreb) explained pertinent new results on the construction of representations of certain vertex algebras. Simon Wood (Canberra) showed that Virasoro minimal models admit C_2-cofinite logarithmic extensions. These theories can also be realized using kernels of screening operators. Alexei Semikhatov (Moscow) discussed how properties of screening charges are naturally captured by Nichols algebras, which can be used to understand such representation categories explicitly. David Ridout (Canberra) explained the necessity to consider simultaneously different parabolic Borel algebras to get consistent representation theories associated with WZW-theories at fractional level.
In a series of lectures, Christian Blanchet (Paris), François Costantino (Strasbourg), Nathan Geer (Utah State), and Bertrand Patureau (Vannes) presented a class of non-semisimple categories constructed as representation categories of a finite-dimensional quantum group that allow one to construct two central pieces of data of a three-dimensional TFT: invariants of at least classes of decorated three-manifolds and representations of mapping class groups of surfaces. Closely related invariants, generalized Kashaev invariants for knots in three-manifolds, were discussed by Jun Murakami (Tokyo). Finally, Christoph Schweigert (Hamburg) explained how to construct, for certain types of non-semisimple categories, invariants of mapping class groups that are candidates for bulk correlation functions of logarithmic conformal field theories.

Outcomes and achievements

We note a few scientific developments that have become manifest during the programme:

- Monoidal categories (possibly with additional structures, e.g. a braiding) have become a powerful lingua franca, allowing for efficient communication across borders between different fields.
- Higher categories have gained increasing importance. Bicategories are by now freely used in talks, three-categorical structures are found in concrete problems. ∞-categories start to pervade the field and strengthen its links to modern trends in algebraic topology.
- Both problems arising in physics, in particular in the study of critical systems, and representation theoretic developments have put three-dimensional TFT-like structures based on non-semisimple tensor categories to the forefront. Much progress has been made concerning these structures on manifolds of codimension 1 and 2. The structures in three dimensions require additional insight. We expect further progress in this field in the coming years.

We also would like to point out some of the new connections that have been established during the programme:

- Developments in the representation theory of Hopf algebras and in the representation theory of infinite-dimensional algebras (Kac-Moody algebras and vertex algebras) have lead to rather similar classes of non-semisimple monoidal categories.
  Prior to this workshop, this convergence had not been realized by the respective communities (including the organizers). These new developments have lead to a major excitement among the participants of the second workshop. In fact, the free afternoon was spontaneously devoted to an additional afternoon session to which almost all participants contributed.

- These non-semisimple categories have the promise to lead to structures rather close to the one of a complete extended three-dimensional topological field theory. It is exciting to speculate that these structures will allow one to extend the TFT approach to rational CFT correlators to larger classes of conformal field theories.

Many participants started discussions in smaller groups. We briefly list some of the discussions that were started and of which we are aware:

- Jesper Jacobsen and Martin Schnabl realized that an equation derived from factorization constraints plays a central role both in open string field theory and in statistical mechanics for systems with boundaries.
- Jürgen Fuchs, Christoph Schweigert, and Martin Schnabl realized structural similarities between the TFT approach to RCFT correlators and structures in open string field theory. We hope that this will provide a more precise handle on string field theory as well as insights into possible extensions of the validity of the TFT approach beyond rational theories.
- Sebastian Burciu and Jeffrey Morton discussed the equivariantization of categories with a group action, as well as some generalizations of Mackey functors and groupoidification.
- Jürgen Fuchs, Christoph Schweigert, and Alessandro Valentino on the one hand and Gregor Schaumann on the other hand realized that it is most beneficial to join their efforts in understanding topological surface defects in three-dimensional topological field theories of Turaev-Viro type.
- Also various existing collaborations were continued during the programme; they include the collaboration of Natale and Burciu on equivariantizations of fusion categories and the collaborations within the String Geometry network.

List of talks

Workshop 1, February 17 – 21, 2014

Dror Bar-Natan	A partial reduction of BF theory to combinatorics
Ulrich Bunke	Differential cohomology theory
Kazuo Habiro	Kirby calculus for null-homologous framed links in 3-manifolds
Theo Johnson-Freyd	AKSZ theory and homotopy actions of properads
Rinat Kashaev	Beta pentagon relations
Catherine Meusburger	Diagrams for Gray categories with duals
Scott Morrison	Progress on small fusion categories
Sonia Natale	On weakly group-theoretical non-degenerate braided fusion categories
Thomas Nikolaus	Twisted differential cohomology
Pranav Pandit	The topological A-model, spectral networks, WKB-theory and buildings
Thomas Schick	Geometric models for higher twisted K-theory
Chris Schommer-Pries	Extended topological field theories and tensor categories
Urs Schreiber	Homotopy-type semantics for quantization
Joost Slingerland	Local representations of the loop braid group
Thomas Strobl	Dirac sigma models and gauging
Ulrike Tillmann	Commutative K-Theory and other new generalised cohomology theories
Boris Vertman	Combinatorial quantum fIeld theory and gluing formula for determinants
Alessandro Valentino	Boundary conditions for 3d TQFTs and module categories
Alexis Virelizier	3-dimensional HQFTs
Kevin Walker	Premodular TQFTs
Mahmoud Zeinalian	A concise construction of differential K-theory

Workshop 2, March 17 – 21. 2014

Drazen Adamovic	On constructions of logarithmic representations for certain vertex algebras
John Barrett	The geometry of matrices and 2d TQFT
Christian Blanchet	Quantum invariants and spin structures
Qingtao Chen	Congruent skein relation and LMOV conjectures
Francesco Costantino	Non semi-simple sl(2) quantum invariants, Part III: TQFTs and mapping class group representations
Azat Gainutdinov	From the deformed Virasoro algebra to Temperley-Lieb algebras
Nathan Geer	Non semi-simple sl(2) quantum invariants, Part I: From links to TQFTs
Jesper Jacobsen	Logarithmic correlations in geometrical critical phenomena
Andrey Lazarev	Unimodular homotopy algebras and Chern-Simons theory
Gregor Masbaum	All finite groups are involved in the mapping class group
Sergei Merkulov	Grothendieck-Teichmller group and exotic automorphisms of the Lie algebra of polyvector fields
Jun Murakami	Generalized Kashaev invariants for knots in three-manifolds
Bertrand Patureau	Non semi-simple sl(2) quantum invariants, Part II: 3-manifold invariants
David Ridout	Module categories for affine VOAs at admissible level
Gregor Schaumann	*-representations for pivotal tensor categories
Martin Schnabl	New look at BCFT's from OSFT
Christoph Schweigert	Invariants for mapping class group actions from ribbon Hopf algebra automorphisms
Simon Wood	Rational logarithmic extensions of the minimal models and their simple modules

String Geometry junior network meeting, February 24 – 28. 2014

Christian Becker	Relative differential cohomology and Chern-Simons theory
Bas Janssens	Representation theory of gauge groups
Thomas Nikolaus	T-duality in K-theory and elliptic cohomology
Joost Nuiten / Urs Schreiber	Cohomological quantization
Ulrich Pennig	An introduction to I-spaces and a conjecture about K(ku)
Christian Voigt	Clifford algebras, fermions, and categorification
Michael Völkl	The intrinsic eta-invariant and geometrizations
Konrad Waldorf	String geometry vs. spin geometry on loop spaces
Christoph Wockel	Topological group cohomology and Chern-Weil theory

Individual talks

Jørgen Andersen	Quantum representations of mapping class groups via geometric quantization of moduli spaces
Sebastian Burciu	Grothendieck groups of equivariantized fusion categories
Alan Carey	A geometric approach to twisted K-homology
Nils Carqueville	Equivariant completion of defect bicategories
Thang Le	The Habiro ring and invariants of 3-manifolds
Jeffrey Morton	Towards extended TQFT from higher gauge theory
Ingo Runkel	Spin from defects in two-dimensional field theory
Alexei Semikhatov	From conformal field theory to Nichols algebras and back

Invited scientists:

Drazen Adamovic, Jorgen Ellegaard Andersen, Dror Bar-Natan, John Barrett, Christian Becker, Klaus Bering, Mette Bjerre, Christian Blanchet, Igor Buchberger, Ulrich Bunke, Sebastian Burciu, Alan Carey, Nils Carqueville, Qingtao Chen, Hongyi Chu, Ben Cooper, Francesco Costantino, Jens Kristian Egsgaard, Jürgen Fuchs, Azat Gaynutdinov, Nathan Geer, Kazuo Habiro, Yonathan Harpaz, Omid Hurson, Jesper Jacobsen, Bas Janssens, Theo Johnson-Freyd, Rinat Kashaev, Ludmil Katzarkov, Christian Krattenthaler, Andrey Lazarev, Thang Le, Simone Marzioni, Gregor Masbaum, Joanna Meinel, Serguei Merkoulov, Catherine Meusburger, Scott Morrison, Jeffrey Morton, Jun Murakami, Sonia Natale, Thomas Nikolaus, Joost Nuiten, Pranav Pandit, Bertrand Patureau-Mirand, Ulrich Pennig, Nicolai Reshetikhin, David Ridout, Ingo Runkel, Ramanujan Santharoubane, Gregor Schaumann, Claudia Scheimbauer, Thomas Schick, Chris Schommer-Pries, Urs Schreiber, Christoph Schweigert , Alexei Semikhatov, Martin Schnabl, Joost Slingerland, Markus Spitzweck, Thomas Strobl, Ulrike Tillmann, Alessandro Valentino, Boris Vertman, Alexis Virelizier, Christian Voigt, Michael Völkl, Konrad Waldorf, Kevin Walker, Christoph Wockel, Simon Wood, Mahmoud Zeinalian.

Combinatorics, Geometry and Physics

Organizers: Abdelmalek Abdesselam (U of Virginia), Christian Krattenthaler (U of Vienna), Adrian Tanasă (Paris North U), Fabien Vignes-Tourneret (CNRS, U Lyon 1)

Dates: June 2 – July 31, 2014

Budget: ESI € 44 800,
Fonds zur Förderung der wissenschaftlichen Forschung (Austrian Science Fonds FWF) € 13 548, Institut Camille Jordan € 4 754, (U Lyon 1 € 2 924, Centre national de la recherche scientifique (CNRS) € 1 830), Agence nationale de la recherche (ANR) € 2 539.

Report on the programme

Combinatorics, geometry and physics is a key frontier, still underdeveloped but promising. Discrete mathematics has been revived during the last century by the advent of computers and quantum mechanics. But combinatorics itself, in contrast with the more traditional areas of algebra, geometry and analysis, has not been yet sufficiently exposed to the main ideas of modern theoretical physics, and the converse is also true. This interface has shown dramatic and accelerating progress in the recent years. Promising and entangled developments have occurred.

The goal of this thematic programme was to bring together researchers in mathematics, computer science and theoretical physics in order to make significant progress on the outstanding problems at the interface of combinatorics, statistical physics and gravity.

Activities

The first point of focus of this programme concerned statistical physics on graphs drawn on two-dimensional surfaces. This has been studied in three stages: on a fixed graph, on a random graph, and finally through the study of the interplay between the last two situations as exemplified by the paradigmatic KPZ relation. The list of topics which have been addressed under this heading includes: graph and topological polynomials, the Potts, $O(1)$ and dimer models, relations to knot theory, matrix models, alternating sign matrices, random planar maps and two-dimensional quantum gravity.

The second point of focus concerned attempts at generalizing the two-dimensional success story to the case of higher-dimensional combinatorial random geometries. Here are some of the main topics which were addressed: (constructive) (tensor) (group) field theory, random tensors, the $1/N$ expansion for tensor models, analogues for tensors of the universality for random matrices, renormalizable models of tensor field theory, (random) simplicial complexes, loop quantum gravity, causal dynamical triangulations, $3D$ topological glasses, knot theory, geometric topology.

Specific information on the programme

During the programme, two workshops and a summer school have been organised. The first workshop has been devoted to “$2D$-quantum gravity and statistical physics” (attended by 30 people), the second one to “Random tensors” (attended by 32 people). The purpose of the two workshops was to have one-week meetings of researchers in all three fields, in which new and ongoing research in combinatorics, geometry and physics, and related areas is presented and discussed, with the goal of deepening the understanding of recently developed theories.

The summer school was held before the two workshops. Its goal was to offer four series of lectures on recent trends at the interface between combinatorics, statistical physics, and quantum gravity to young researchers at the pre- and post-doctoral level. 38 participants attended the lectures. They were mainly PhD students, but not exclusively. The programme of the school was the following:

Di Francesco, Philippe: *Matrix models and map combinatorics*.

We reviewed the techniques of matrix integration and their application to the enumeration of (decorated) maps, used in the context of two-dimensional quantum gravity. We further presented the methods of enumeration of maps via bijections with trees, that give a direct combinatorial interpretation of the matrix model solution, and allow one to go beyond and study the intrinsic geometry of random maps.

Course outline:

0. A brief introduction to statistical physics
1. Gaussian integrals and graphs
2. Matrix Gaussian integral and maps
3. Model building with matrices
4. The one-matrix model I: angular integration
5. The one-matrix model II: orthogonal polynomials
6. Planar map combinatorics
7. Higher genus and integrable hierarchies
8. The double scaling limit
9. Geodesic distances and bijections with trees
10. Integrability in discrete systems

Guionnet, Alice: *Loop Equations, Topological Expansions and Universality in Random Matrix Models*.

It is well known that moments of random matrices can be seen as generating functions for the enumeration of maps, that is, graphs sorted by their genus. Even though this relation can be

deduced in many cases by the Wick formula and the computation of Gaussian moments, it can also be encoded into equations for the correlators of random matrix models. We discussed this relation and how it can be used to obtain asymptotic topological expansions for various matrix models. We then investigated how such ideas can be extended to study the local fluctuations of the spectrum of matrix models.
These lectures were based on joint work with F. Bekerman, G. Borot, B. Collins, A. Figalli, K. Kozlowski, E. Maurel-Segala, J. Novak, and D. Shlyakhtenkho.

Gurau, Razvan: *Introduction to Random Tensors*.

We gave an introduction to the theory of random tensors. Random matrices encode a theory of random two dimensional surfaces. In higher dimensions, they generalize to random tensors, which encode a theory of random higher dimensional spaces. Like random matrices, random tensors support a "$1/N$" expansion and an analytically controlled large N limit.

1. Introduction
   - tensors, invariants and edge colored graphs
   - faces, bubbles and the dual triangulation
   - jackets and the degree
2. Tensor Models
   - Feynman graphs
   - the $1/N$ expansion
   - melonic graphs
3. Beyond perturbation theory
   - Borel summability
   - the BKAR formula
   - the rigorous $1/N$ expansion

Moffatt, Iain: *Graph Polynomials in Knot Theory*.

This series of lectures provided an introduction to some key ideas in graph polynomials and knot theory, with an emphasis on how these two areas interact with each other. I initially focussed on the Tutte polynomial of a graph, describing how it arises in knot theory via Reshetikhin-Turaev knot invariants and statistical mechanics, and outlined some of its applications. I then described the appearances and applications of various other graph polynomials in knot theory, including the Bollobas-Riordan and interlace polynomials.

Outcomes and achievements

One of the main goals of this programme was to foster new collaborations and strengthen existing ones, at the frontier of combinatorics, geometry, and physics. Among the new ones, let us cite the following:

S. Chmutov, F. Vignes-Tourneret: They introduce a collection of new operations on hypermaps, partial duality, which include the classical Euler-Poincaré dualities as particular cases [CV14]. These operations generalize the partial duality for maps, or ribbon graphs, recently discovered in a connection with knot theory. Partial duality is different from previous studied operations of S. Wilson, G. Jones, L. James, and A. Vince. Combinatorially hypermaps may be described in one of three ways: as three involutions on the set of flags (τ-model), or as three permutations on the set of half-edges (σ-model in orientable case), or as edge 3-colored graphs. They express partial duality in each of these models.

S. Dartois, R. van der Veen: They study knot complements and their triangulations via tensor field theory methods.

É. Fusy, A. Tanasa: Three-dimensional random tensor models are a natural generalization of the celebrated matrix models. The associated tensor graphs, or $3D$ maps, can be classified with respect to a particular integer or half-integer, the degree of the respective graph. In this paper [FT14] they analyze the general term of the asymptotic expansion in N, the size of the tensor, of a particular random tensor model, the multi-orientable tensor model. They perform their enumeration and establish which are the dominant configurations of a given degree.

T. Krajewski, I. Moffatt, A. Tanasa: This collaboration aims at establishing a non-trivial connection between some appropriate ribbon graph (and Delta-matroid) Hopf algebras and ribbon graph (and Delta-matroids) polynomials (Bollobas-Riordan and Penrose).

The programme also allowed already existing collaborations to produce new results:

J. Ellis-Monaghan, I. Moffatt: They observe that list coloring in graph theory coincides with the zero-temperature antiferromagnetic Potts model with an external field [EM14a]. They give a list coloring polynomial that equals the partition function in this case. This is analogous to the well-known connection between the chromatic polynomial and the zero-temperature, zero-field, antiferromagnetic Potts model. The subsequent cross fertilization yields immediate results for the Potts model and suggests new research directions in list coloring.

R. Gurau, T. Krajewski: The generating function of the cumulants in random matrix models, as well as the cumulants themselves, can be expanded as asymptotic (divergent) series indexed by maps. While at fixed genus the sums over maps converge, the sums over genera do not. In this paper [GK14] they obtain alternative expansions both for the generating function and for the cumulants that cure this problem. They provide explicit and convergent expansions for the cumulants, for the remainders of their perturbative expansion (in the size of the maps) and for the remainders of their topological expansion (in the genus of the maps). They show that any cumulant is an analytic function inside a cardioid domain in the complex plane and prove that any cumulant is Borel summable at the origin.

R. Peled, D. Romik: The dense O(1) loop model is a statistical physics model with connections to the quantum XXZ spin chain, alternating sign matrices, the six-vertex model and critical bond percolation on the square lattice. When cylindrical boundary conditions are imposed, the model possesses a commuting family of transfer matrices. The original proof of the commutation property is algebraic and is based on the Yang-Baxter equation. In this paper they give a new proof of this fact using a direct combinatorial bijection.

The Erwin Schrödinger International Institute provided, as usual, excellent working conditions. It is illustrated by the fact that E. Kalfagianni [KR14] and S. Dartois [Dar14] finished a paper while staying at the ESI, and F. David [Dav15] gave the final touch to his book on Quantum Mechanics.

Note also that A. Guionnet (in collaboration with G. Borot), R. Gurau and I. Moffatt will write lecture notes corresponding to the course they delivered at the ESI.

Publications and preprints contributed:

[BB14] O. Bernardi and M. Bousquet-Mélou. “Counting coloured planar maps: differential equations”. 2014.

[CV14] S. Chmutov and F. Vignes-Tourneret. “Partial Duality of Hypermaps”. Sept. 1, 2014. arXiv: 1409.0632 [math.CO].

[Dar14] S. Dartois. “A Givental-like Formula and Bilinear Identities for Tensor Models”. Sept. 19, 2014. arXiv:1409.5621 [math-ph].

[Dav15] F. David. “The Formalism of Quantum Mechanics: an Introduction”. Vol. 893. Lecture Notes in Physics. Springer, 2015. VII+157pp.

[DG14] B. Duplantier and A. Guttmann. “The critical exponent for self-avoiding bridges”. 2014.

[EM14a] J. Ellis-Monaghan and I. Moffatt. “A note on recognizing an old friend in a new place: list coloring and the zero-temperature Potts model”. To appear in Ann. Inst. H. Poincaré, 2014. arXiv: 1406.5532 [math.CO].

[EM14b] J. Ellis-Monaghan and I. Moffatt. “The Las Vergnas Polynomial for embedded graphs”. 2014. arXiv:1311.3762v2 [math.CO].

[FT14] É. Fusy and A. Tanasa. Asymptotic expansion of the multi-orientable random tensor model”. Aug. 25, 2014. arXiv:1408.5725 [math.CO].

[GK14] R. Gurau and T. Krajewski. “Analyticity results for the cumulants in a random matrix model”. Sept. 5, 2014. arXiv:1409.1705 [math-ph].

[KR14] E. Kalfagianni and C. Ruey Shan Lee. “Crosscap numbers and the Jones polynomial”. Sept. 1, 2014. arXiv:1408.4493 [math.GT].

[KSS14] C. Koutschan, E. Suazo, and S. Suslov. “Multi-parameter Laser Modes in Paraxial Optics”. July 9, 2014. arXiv: 1407.0730 [physics.optics].

[PR14] R. Peled and D. Romik. “Bijective combinatorial proof of the commutation of transfer matrices in the dense $O(1)$ loop model”. July 21, 2014. arXiv: 1407.5357 [math-ph].

Invited scientists:

Abdelmalek Abdesselam, Roger Behrend, Sabine Beil, Bruno Benedetti, Olivier Bernardi, Mireille Bousquet-Mélou, Jeremie Bouttier, Valentin Bonzom, Zakaria Chemli, Sergei Chmutov, Mihai Ciucu, Benoit Collins, Yoann Dabrowski, Stéphane Dartois, Francois David, Thibaut Delepouve, Philippe Di Francesco, Beatrice de Tilliere, Bianca Dittrich, Gerard Duchamp, Bertrand Duplantier, Jean-Pierre Eckman, Theresia Eisenkölbl, Joanna Ellis-Monaghan, Ilse Fischer, Motohisa Fukuda, Éric Fusy, Harald Grosse, Alice Guionnet, Razvan Gurau, Tony Guttmann, Ouraman Hajizadeh, Nils Haug, Kristof Zoltan Huszar, Matthew Kahle, Efstratia Kalfagianni, Spyridon Kamvissis, Vladimir Kazakov, Christoph Koutschan, Thomas Krajewski, Christian Krattenthaler, Vincent Lahoche, Renate Loll, Camille Male, Diana Suzana Mandar, Konstantin Matveev, Martin Meier, Iain Moffatt, Alexi Morin-Duchesne, Taro Nagao, Daniele Oriti, Florin Panaite, Frederic Patras, Eveliina Peltola, Fedor Popov, Adrien Poncelet, Aldo Procacci, Sanjay Ramassamy, Sanjaye Ramgoolam, Vincent Rivasseau, Dan Romik, James Ryan, Sjabbo

Schaveling, Jeanne Scott, Valentin Slepukhin, Benjamin Smith, Neal Stoltzfus, Sergei Suslov, Adrian Tanasă, Reiko Toriumi, Roland van der Veen, Xavier Viennot, Fabien Vignes-Tourneret.

Topological Phases of Quantum Matter

Organizers: Nicholas Read (Yale U), Jakob Yngvason (U Vienna), Martin Zirnbauer (U Cologne)

Dates: August 4 – September 12, 2014

Budget: ESI € 50 400,
Deutsche Forschungsgemeinschaft (DFG) (ZI-513/1-2) € 25 000, DFG (SFB/TR 12) € 30 000, American Institute of Physics (AIP) $ 1 000.

Report on the programme

In the foundational realm of quantum phases of condensed matter, the past decade has seen the concept of "topological invariants" emerge as a new paradigm beyond that of Landau-Ginzburg-Wilson. While the relevance of topology for the classification of bulk-insulating phases had been known since the early days of the quantum Hall effect, the subject recently received renewed impetus by the theoretical and experimental discovery of novel topological phases for time-reversal invariant electron systems with strong spin-orbit coupling. Building on this impetus, the programme brought together a selected group of physicists and mathematicians with the goal of disseminating and stimulating mathematical physics research in the area of topological quantum matter. Specific goals were to consolidate the understanding of free-fermion ground states with symmetries, and to further develop the tools needed to handle disorder and/or interactions.

Activities

The time table of the programme was as follows:

- August 4–8: Week of Introductory Lectures
- Aug 9 – Sept 7: Core of the Programme
- September 8–12: Final Conference

The ESI-Programme started with a full week (Monday to Friday) of introductory lectures as a service to the local community of researchers, to PhD students working in the field or starting to work in it, and to postdocs interested in entering the field. There were four lectures per day (two in the morning, two in the afternoon). These introductory lectures were as elementary as possible, giving the relevant history and background of the subject, and leading up to the main ideas behind current developments. The lectures were given by Y. Avron, J. Bellissard, C.M. Marcus, M. Morgenstern, N. Read, S. Ryu, F. Verstraete, X.-G. Wen, covering the following list of topics: history of the subject rooted in the Quantum Hall Effect (QHE), noncommutative geometry approach to the QHE, status of current experiments, fractional quantum Hall effect, classification of topological insulators and superconductors, tensor network states, entanglement, topological order and symmetry-protected topological phases.

The core of the programme was filled with informal discussions and a series of talks (2 per day) by the participants in residence. The programme concluded with a conference organized in cooperation with the DFG-funded Collaborative Research Center 12 (Cologne-Bochum-Duisburg/Essen-Munich-Warsaw).

As a satellite event, there was an Intensive Week "Tools of Topology for Quantum Matter" (July 28 – August 1) staged at Cologne University under the auspices of the Bonn-Cologne Graduate School of Physics & Astronomy.

Specific information on the programme

The participants of the programme were drawn from a variety of backgrounds ranging from experimental physics (C.M. Markus, M. Morgenstern) to topological field theory (J. Fuchs, C. Schweigert). Our broad approach to the subject was appreciated as useful by partipants from both ends of the spectrum; while it did not lead to immediate joint publications, it did give rise to numerous informative discussions. The main target and primary beneficiaries of the broad approach was the group of young researchers including 20 PhD students and 15 junior postdocs from a total of 24 different institutions.

Outcomes and achievements

Participants were unanimous in giving praise to Yosi Avron (Haifa) and Jean Bellissard (Georgia Tech) for delivering very stimulating opening lectures. In particular, Bellissard's lectures on the noncommutative geometry approach to the quantum Hall effect were highly appreciated by participants from condensed matter theory and are expected to have an impact on current and future developments in the field of topological insulators with disorder. In this subfield, the programme hosted a strong activity due to the presence and mutual interaction between a number of researchers (H. Schulz-Baldes, E. Prodan, T. Loring, plus postdocs and students). According to an opinion shared by several participants, one may now hope to make mathematical progress even with fractional quantum Hall systems, by employing KK-theory.

Many participants were stimulated by the exposure to ideas surrounding tensor network states. These were expounded to the programme participants by the lectures of F. Verstraete and X.-G. Wen and then elaborated in a series of research talks (J. Dubail, N. Schuch, H.-H. Tu, Z.-C. Gu, J.C. Budich). This subactivity has already resulted in new collaborations and several preprints (including no. 7 of the list above).

Further highlights of the programme were a well-prepared and well-delivered series of lectures (accompanied by a 120 page write-up which is available at `http://www.physics.rutgers.edu/~gmoore/ViennaLecturesF.pdf`) by Greg Moore and two talks by Duncan Haldane on a novel geometric view of fractional quantum Hall states. Another noteworthy outcome was the initiation of a major review article on "classification of topological quantum matter with symmetries" by participants A. Schnyder, S. Ryu, and J. Teo (jointly with C.-K. Chiu).

In spite of the high seminar frequency maintained throughout the programme, there were many discussions during breaks and on the weekends, some of them between participants *who met for the first time*; thus, J. Fuchs and C. Schweigert had useful exchanges with X.-L. Qi; M. Lein and G. de Nittis with D. Haldane and M. Zirnbauer; T. Loring with H. Schulz-Baldes; V. Gurarie with T. Quella; to name just a few examples.

List of talks

Week of Introductory Lectures, August 4 – 8, 2014

Markus Morgenstern	Topological properties in solids probed by experiment
Yosi Avron	Platonic quantum Hall effect (2 lectures): 1. Chern number, 2. Fredholm index
Nicholas Read	Topological phases of matter (3 lectures): 1. Quantum Hall effect and Laughlin states 2. Conformal field theory and non-abelian statistics 3. p+ip paired states and Majorana zero modes
Shinsei Ryu	Periodic table of topological insulators and superconductors (3 lectures): 1. Invariants built from Bloch wave functions 2. Anderson delocalization at the boundary 3. K-theory; interactions
Jean Bellissard	Noncommutative geometry approach to topological invariants in condensed matter physics (3 lectures)
Charles M. Marcus	Majorana modes in semiconductor nanowires?
Frank Verstraete	Classifying topological states using quantum tensor networks (3 lectures)
Xiao-Gang Wen	Quantum entanglement, topological order, and tensor category theory (3 lectures)

Core of Programme, August 11 – September 5, 2014

M. Stone	Berry curvature, spin and anomalous velocity
J. Teo	Twist liquids and gauging anyonic symmetries
T.L. Hughes	Spatial symmetry protected topological phases and geometry
E. Prodan	The noncommutative geometry of the complex classes of topological insulators: analysis and simulation
N. Schuch	Topological order and chirality in projected entangled-pair states
T. Loring	Joint pseudospectra and the K-theory of local energy gaps
S. Ryu	Hydrodynamic effective field theories of topological insulators
V. Gurarie	Hall viscosity, shift, and topological invariants
G.W. Moore	4 lectures: 1. Quantum symmetries and the 3-fold Way 2. Phases of gapped systems and the 10-fold Way 3. Free fermions, the Altland-Zirnbauer classification, and Bott periodicity 4. K-theory classification and application to topological band theory
J.E. Moore	Abelian and non-Abelian gauge fields in the Brillouin zone for insulators and metals
N. Read	Hall viscosity
M. Barkeshli	Extrinsic defects and possible new experimental probes of topological order
A.W.W. Ludwig	Spin liquids on the Kagome lattice: chiral topological, and gapless non-Fermi liquid phase
P. Horava	Multicritical symmetry breaking and resistivity of strange metals
Z.-C. Gu	Classification of symmetry-protected topological phases in interacting fermion and boson systems
J. Fröhlich	The growth of cosmic magnetic fields
H. Schulz-Baldes	Indices of Fredholm operators with symmetries
A. Roy	Defects in lattice anyon models
F.D.M. Haldane	Quantum geometry of the fractional quantum Hall fluids and other topological matter
J. Dubail	Tensor network states and chiral phases of matter
M. Lein	An exhaustive classification of photonic topological insulator
H.-H. Tu	Projected entangled-pair states for chiral topological phases

A. Carey	Spectral flow and operators with essential spectrum
X.-L. Qi	Layer construction of 3D topological states and string braiding statistics
A. Akhmerov	Reducing and increasing the dimensionality of topological insulators
A. Sawicki	n-particle quantum statistics on graphs
T. Quella	Topological phases of fractionalized Majorana fermions (parafermions) in one dimension
G. de Nittis	Differential geometry for time-reversal symmetric Bloch bundles
J.C. Budich	Dissipative Chern insulators
J. Fuchs	Twist defects in topological multilayer systems
K. Duivenvoorden	Topological quantum error correcting codes
P. Werner	Tuning material properties by light

Final Conference, September 8 – 12, 2014

Y. Avron	Braiding fluxes in Pauli Hamiltonians
J. Yngvason	Incompressibility estimates in the Laughlin phase
R. Seiringer	Validity of spin wave theory for the quantum Heisenberg model
S. Diehl	Dissipatively induced quantum phases of atomic fermions
J. Kellendonk	Topological interpretation of Levinson's theorem
A. Altland	Quantum criticality of the topological Anderson insulator
R. Kennedy	Homotopy theory of topological insulators
J. Bellissard	Periodic approximant to aperiodic Hamiltonian
P. Fendley	Parafermions and topological order
K. Flensberg	Tunneling spectroscopy of Majorana bound states
R. Egger	Topological Kondo effect
A. Huckleberry	Constructions in low-dimensional complex geometry related to topological insulators and their symmetry classes
S. Trebst	Chiral spin liquids, network models, and fractional quantum Hall states
M. Hermanns	Majorana metals and quantum spin liquids
C. Schweigert	Topological surface defects, symmetries and dualities
Z.-C. Gu	Emergence of p+ip superconductivity in 2D strongly correlated Dirac fermions
G.-M. Graf	Bulk-boundary duality for topological insulators
X.-L. Qi	Generalized Kitaev models and slave genons
A. Rosch	Skyrmions and emergent monopoles in chiral magnets
I. Bloch	Probing and controlling topological Bloch bands using ultracold quantum gases
T. Quella	Topological aspects of SU(N) magnetism and its cold atom realization
A. Akhmerov	Breaking Kramers degeneracy by superconducting phase differences
J. Fröhlich	Gauge theory of states of matter – old and new
R. Bondesan	Lattice conformal fields at quantum Hall transitions
B. Nachtergaele	Invariants for gapped ground state phases in dimensions one and higher
E. Ardonne	Constructing critical spin chains using modular invariance
H. Schulz-Baldes	Invariants of disordered topological insulators
H. Siedentop	Dipoles in 2d have infinitely many bound states
I. Eremin	Proximity-induced magnetization dynamics, interaction effects, and phase transitions on a topological surface

Publications and preprints contributed:

1. D. Fiorenza, D. Monaco, G. Panati, $\mathbb{Z}_2$ *invariants of topological insulators as geometric obstructions*, arXiv:1408.1030

2. D. Monaco, G. Panati, *Symmetry and Localization in Periodic Crystals: Triviality of Bloch Bundles with a Fermionic Time-Reversal Symmetry*, Acta Applicandae Mathematicae (to appear)

3. C.-K. Chiu, A.P. Schnyder, *Classification of reflection-symmetry-protected topological semimetals and nodal superconductors*, Phys. Rev. B **90**, 205136 (2014).

4. H. Song, M. Hermele, *Space group symmetry fractionalization in a family of exactly solvable models with $\mathbb{Z}_2$ topological order*, arXiv:1409.1504
5. R. Kennedy, M.R. Zirnbauer, *Bott periodicity for $\mathbb{Z}_2$ symmetric ground states of gapped free-fermion systems*, arXiv:1409.2537
6. R. Bondesan, J. Dubail, A. Faribault, Y. Ikhlef, *Chiral* $\mathrm{SU}(2)_k$ *currents as local operators in vertex models and spin chains*, arXiv:1409.8590
7. S. Yang, T.B. Wahl, H.-H. Tu, N. Schuch, J.I. Cirac, *Chiral projected entangled-pair state with topological order*, arXiv:1411.6618
8. P. Werner, R. Sakuma, F. Nilsson, F. Aryasetiawan, *Dynamical screening in* La_2CuO_4, arXiv:1411.3952
9. Y. Du, C. Niu, Y. Tian, H. Zhang, *Holographic vortex pair annihilation in superfluid turbulence*, arxiv:1412.8417

Invited scientists:

Anton Akhmerov (TU Delft), Eddy Ardonne (Stockholm), Yosi Avron (Technion, Haifa), Maissam Barkeshli (Stanford Univ), Siegfried Beckus (U Jena), Jean Bellissard (Georgia Tech), Roberto Bondesan (Cologne), Barry Bradlyn (Yale Univ), Tomas Brauner (U Vienna), Jan Carl Budich (Stockholm), Nick Bultinck (U Gent), Alan Carey (ANU Canberra), Matthew Cha (UC Davis), Guiseppe de Nittis (Erlangen), Jerome Dubail (Nancy), Kasper Duivenvoorden (Aachen), Paul Fendley (Oxford), Jürg Fröhlich (ETH Zürich), Jürgen Fuchs (Karlstad, Sweden), Gian-Michele Graf (ETH Zürich), Julian Grossmann (Erlangen), Zheng-Cheng Gu (CalTech), Victor Gurarie (Boulder), Duncan Haldane (Princeton Univ), Petr Horava (UC Berkeley), Taylor L. Hughes (UIUC), Chao-ming Jian (Stanford Univ), Johannes Kellendonk (Lyon), Ricardo Kennedy (Cologne), Max Lein (Toronto), Yunlong Lian (Cologne), Terry Loring (U NM Albuquerque), Andreas Ludwig (UCSB), Charles M. Marcus (Copenhagen), Domenico Monaco (SISSA Trieste), Joel E. Moore (UC Berkeley), Greg W. Moore (Rutgers Univ), Heidar Moradi (Perimeter Inst), Markus Morgenstern (Aachen), Bruno Nachtergaele (UC Davis), Gianluca Panati (Rome, Sapienza), Jochen Peschutter (Cologne), Emil Prodan (Yeshiva Univ), Thomas Quella (Cologne), Xiao-Liang Qi (Stanford Univ), Nicholas Read (Yale Univ), Abishek Roy (Cologne), Shinsei Ryu (UIUC), Burak Sahinoglu (U Vienna), Adam Sawicki (MIT), Andreas Schnyder (MPI Stuttgart), Norbert Schuch (Aachen), Hermann Schulz-Baldes (Erlangen), Christoph Schweigert (Hamburg), Michael Stone (UIUC), Hao Song (Boulder), Jeffrey Teo (UIUC), Guo Chuan Thiang (Oxford), Daniele Toniolo (NTNU Trondheim), Hong-Hao Tu (MPQ Garching), Jascha Ulrich (Aachen), Frank Verstraete (U Vienna & Gent), Fredy Vides (U NM Albuquerque), Xiao-Gang Wen (Perimeter Inst), Philipp Werner (Fribourg), Dominic Williamson (U Vienna), Jakob Yngvason (ESI Vienna), Amanda Young (UC Davis), Hongbao Zhang (Brussels), Martin Zirnbauer (Cologne).

Minimal Energy Point Sets, Lattices and Designs

Organizers: Christine Bachoc (U Bordeaux), Peter Grabner (Graz U of Technology), Edward B. Saff (Vanderbilt U, Nashville), Achill Schürmann (U Rostock)

Dates: September 29 – November 21, 2014

Budget: ESI € 47 520,
Technical University TU Graz € 12 700 and Fonds zur Förderung der wissenschaftlichen Forschung (FWF) € 2 500 [2].

[2]Project F5503 (part of the Special Research Programme (SFB) "Quasi-Monte Carlo Methods: Theory and Applications")

Report on the programme

The aim of this programme was to bring together mathematicians and scientists (especially physicists) for the purpose of gaining a better understanding of the structure of particle systems under a variety of physical constraints. The subject includes, for example, classical ground states for interacting particle systems, best-packing, random packings, jammed states, granular and colloidal systems, as well as minimal discrete and continuous energy problems for general kernels. The common thread that runs through these subjects is that they are related to problems of optimality under various physical constraints. Of particular interest is that of systems of particles interacting through a pairwise potential and restricted to the unit sphere $\mathbb{S}^d$ in $\mathbb{R}^{d+1}$. This is the classical Thomson problem in the case $d = 2$ with the Coulomb potential. Such problems on the sphere are related to spherical designs, coding theory, viral morphology and Voronoi decompositions. Specifically, the programme has focused on (i) relationships between geometrical, topological, and combinatorial properties of a manifold that are reflected in the asymptotics of minimal energy problems; (ii) the analysis and development of statistical mechanical models from first principles; (iii) tilings and Voronoi decompositions; (iv) high dimensional sphere packings; (v) the geometry of the structure of jammed and near optimal configurations.

Activities

During the programme, two workshops were organised:

- **Optimal Point Configurations and Applications**, October 13 - 17, 2014:
  this workshop started with two preparatory lectures by H. Cohn and D. Hardin on October 12, which were aimed especially to doctoral students and PostDocs, but were attended by most of the participants. The workshop itself was aimed at the subject of point sets or particle systems under various optimality conditions. The talks given at the workshop covered the subject from the points of view of particle physics, crystallography, numerical integration, approximation theory, potential theory, and several others.

- **Sphere Packings, Lattices, and Designs**, October 27 - 31, 2014:
  also this second workshop started with two lectures by R. Coulangeon and F. Vallentin on Sunday, October 26, which were aimed to prepare the participants for the subject. The workshop dealt with point configurations from a geometric and algebraic point of view. The talks covered new developments in the theory of designs, packing problems, Voronoi theory, lattices, and others.

In the weeks before the first workshop and between the workshops a smaller number of participants were present at the ESI. This allowed for various interactions, which should lead to publications in the near future.

The organisers want to especially emphasise that the ESI staff was very helpful and efficient during the whole programme as well as in the period of preparation. Without their continuous support a programme of this size would have been impossible to organise. The ESI facilities offering office space for every participants and ample space for discussion and informal meeting was also essential for the success of the programme.

Specific information on the programme/workshop

It was a major goal of the organisation of the programme to invite PhD-students and young PostDocs; as mentioned above, special preparatory lectures were organised for these participants. In the course of the preparation of the programme the organisers approached the participants to nominate doctorands and young PostDocs, who should participate in the programme. On the basis of these proposals the following participants have been invited: Moritz Antlanger, Sören Lennart Berg, Laurent Bétermin, Jingguo Bi, Mitia Duerinckx, Erik Friese, Tobias Jakobi, Tamas Korodi, Wöden Kusner, David de Laat, Giovanni Lazzarini, Romanos Malikiosis, Lev Markhasin, Jordi Marzo, Timothy Michaels, Gregory Minton, Maren Helene Ring, Dima Shiryaev, Marcel Silva, Brian Simanek, Yujian Su, Xun Sun, Khan Trang, Mario Ullrich, Oleksandr Vlasiuk, Yuguang Wang, Ziqing Xiang, Wei-Hsuan Yu, Peter Zeiner, Kai Zhang, Yan Zhu, Marc Christian Zimmermann. The programme gave them the opportunity to get in contact with leading experts in their field and thus had a positive influence on their career development.

Minimal energy point sets This subject went through an intensive development in the last decade. This is partly due to D. Hardin's and E. Saff's proof that optimal point configurations under a hypersingular potential are asymptotically uniformly distributed. It is also partly due to works in connection with the recently introduced new concept of universal optimality by H. Cohn and A. Kumar. The workshop gave a very good insight into the developments since then. A very recent new impact is due to S. Serfaty and her group, who developed a new method, which allows for the derivation of higher order asymptotic expansion of the minimal energy. Higher order asymptotic results for the periodic energy problem were also presented by for the periodic energy problem were presented by Y. Su who reported on joint work with D. Hardin, E. Saff and B. Simanek.

Ordered and disordered media The subject of energy minimisation has one of its sources in physics. There were several contributions about particle systems, phase transitions in their local and global order or disorder, geometry of carbon structures, and the structure of ground states under various external influences. It is noteworthy that several researchers from Viennese research groups took the opportunity to join the programme.

Numerical integration and approximation The general idea of minimising energy functionals led to several constructions of point sets with good distribution behaviour, one of them being the most recently introduced concept of QMC-designs. All these constructions share the applicability in numerical integration and as sample points for approximation of functions. Several contributions were devoted to this subject area.

Spherical designs The interest in spherical designs is rather diverse, ranging from the algebraic concept of association schemes, over the geometry of certain extremal lattices to their application in numerical integration. The rather recent proof of the existence of spherical designs of optimal growth order by A. Bondarenko, D. Radchenko, and M. Viazovska had a great impact on the development of the subject. Further connections were pointed out in M. Ehler's talk, where designs on the Grassmannian were used for numerical applications.

Packing problems Packing of space by congruent copies of a given body is a classical problem in geometry. The completion of a proof of the Kepler conjecture by T. Hales focused the interest in such questions. Several talks were devoted to related subjects, such as packing the plane by pentagons, or applications of packing results to frames in harmonic analysis.

Lattices and Voronoi theory Well rounded and extremal lattices, geometry of numbers, number theoretic questions such as the computation of unit groups, spectra of lattices, and the phase transitions in random packing lattices were subjects of talks in this context.

Outcomes and achievements

In the following we list cooperations initiated and research papers started during the programme. This list is based on the responses from the participants and is far from exhaustive. The atmosphere at ESI was very conducive to conversations that will lead to further cooperation and research publications.

Christine Bachoc has been able to pursue her ongoing collaboration with Martin Ehler about applications of configurations of points in Grassmannian space to signal processing during her one month stay at ESI (0ctober 1 - November 1). The topics they have been working on are: The phase retrieval problem for subspace projections, and the notion of designs in real and complex projective geometry, and its analogies with the notion of Euclidean designs.

Mikhail Bouniaev discussed potentials for joint projects with other presenters and participants , in particular with P. Boyvalenkov, P. Dragnev, and M. Stoyanova.

Johann Brauchart brought a joint paper with J. Dick, E. Saff, I. Sloan, and Y. Wang on the properties of random point distributions on the sphere close to completion. He continued existing cooperations with P. Dragnev, D. Hardin, E. Saff, and X. Sun. A new possible collaboration with D. Bilyk was established. Furthermore, he finished the paper "Explicit formulas for the Riesz energy of the Nth roots of unity" submitted to the Proceedings of Constructive Functions 2014 (in honor of Ed Saff's 70th birthday)

Lenny Fukshansky initiated new collaborations with A. Schürmann, S. Robins, M. Henk, J. P. Rossetti, R. Malikiosis, R. Coulangeon, C. Bachoc, and many others on the interplay between approximation theory, mathematical physics, and applied mathematics, with the theory of lattices and discrete geometry.

Paul Leopardi renewed his contact with C. Beltrán on the relationship between their research findings concerning energy on the unit sphere.

Yoav Kallus started a collaboration with Wöden Kusner on showing local optimality of various double lattice packings in the plane.

Francis Narcovich exchanged ideas with E. Saff, D. Hardin, and J. Ward on how to develop a way of precisely describing locally quasi uniform data on the sphere and other manifolds.

Achill Schürmann had the opportunity to pursue three research projects (forthcoming papers) during his stay.

1. a forthcoming paper with M. Dutour Sikiric, about the computer assisted classification of Combinatorial Types of Dirichlet Voronoi cells of five dimensional lattices. This computation goes far beyond the known classical classifications by Fedorov, Delone and Stogrin in dimensions 3 and 4.
2. a joint work with Renaud Coulangeon on the universal local optimality of the 2-periodic set D_9^+. Being separated, there had been no progress for more than a year. During the common stay at the ESI some major progress has been made that now has to be worked out in detail over the coming weeks. This is a very nice example for research that would not have been possible without an exceptional programme as offered by the ESI.

3. the foundations for a new type of algorithm that allows to compute certificates for a matrix to be completely positive were laid together with F. Vallentin and M. Dutour Sikiric. At the ESI they were able to not only come up with new ideas, but also to work out a plan for the coming month. Entering this new field of research would not been possible without the opportunity to intensively work together in Vienna.

Sylvia Serfaty will cooperate with D. Hardin and E. Saff during a month-long spring visit to the University of Paris, 6 in spring 2015, which was initiated at the ESI.

Michael Shub collaborated with D. Hardin on the problem of placing points on the 2-sphere and Smale's 7th problem. This problem arose in joint work that Shub and Smale did on polynomial root finding in the 1990's. The progress obtained will be mentioned in a Plenary talk at FoCM meeting in Montevideo.

Salvatore Torquato started a new cooperation with J. Brauchart, P. Grabner, and W. Kusner on hyperuniformity of point distributions on compact domains, especially the sphere.

Emmanuel Trizac continued his work with colleagues from Vienna (especially M. Antlanger, who attended the workshop) on the ground state of asymmetric charged bilayers.

Natalia Zorii was collaborating with P. Dragnev, D. Harding, and E. Saff in potential theory. Their efforts have been concentrating on the minimum Riesz energy problems with an external field for a condenser with touching plates, in particular on the question of their solvability. The conditions obtained are given either in terms of variational inequalities for the weighted potentials, or in geometric-potential terms for the plates. A detailed analysis of the properties of the minimising weighted potentials and the supports of the minimisers has been provided as well. A publication on this subject is close to being completed.

One long term achievement of the programme at the ESI is the continuation of the fruitful series of meetings devoted to the subject.

- E. Saff and S. Serfaty are currently organising a meeting "From statistical physics to approximation theory" to be held at end of June 2016 in Paris.
- A proposal for a special semester on "Point Configuration in Geometry, Physics and Computer Science" at the Institute for Computational and Experimental Research in Mathematics (ICERM) to be held in 2018 was submitted by C. Bachoc, H. Cohn, P. Grabner, D. Hardin, E. Saff, A. Schürmann, S. Serfaty, and S. Torquato. The pre-proposal has already been accepted by the ICERM board.

List of talks

First Workshop: Optimal Point Configurations and Applications, October 13 – 17, 2014:

Ian Sloan	QMC designs and covering of spheres by spherical caps
Johann Brauchart	Covering and Separation for points on the sphere
Jordi Marzo	Uniformly bounded sets of orthonormal polynomials on the sphere
Braxton Osting	Spectrally Optimized Point Set Configurations
Salvatore Torquato	Disordered Energy Minimizing Configurations
Emmanuel Trizac	The Wigner Crystal problem for charged bilayers
Ladislav Šamaj	Ground-state of charged particles between the walls with dielectric images
Moritz Antlanger	The asymmetric Wigner bilayer problem
Peter Dragnev	Universal lower bounds for potential energy of spherical codes
Carlos Beltrán	Optimal distribution of heat sources in the sphere
Paul Leopardi	Discrepancy, separation and Riesz energy of finite point sets on compact connected Riemannian manifolds
Kenneth Stolarsky	Thinking Outside the Circle
Sylvia Serfaty	Next order asymptotics of large systems with Coulomb and Riesz interactions
Laurent Bétermin	Asymptotic expansion of logarithmic energy on the sphere
Brian Simanek	Periodic Discrete Energy

Yujian Su	The Next-order Term for Minimal Periodic Riesz Energy Asymptotics
Josef Dick	Numerical integration on the sphere using quasi-Monte Carlos rules
Dmitriy Bilyk	The L^2 discrepancy of Fibonacci (and other) lattices
Lev Markhasin	BMO and exponential Orlicz space estimates of the discrepancy function in arbitrary dimension
Mario Ullrich	Frolov cubature in Besov spaces with mixed smoothness
Henry Cohn	Optimal simplices and codes in projective spaces
Joe Ward	Local Bases on Spheres with Applications
Francis Narcowich	A Zeros Lemma for Riemannian Manifolds
Yuguang Wang	Computation of isotropic random fields on spheres via needlets decomposition
Khang Tran	The root distribution of polynomials with a three-term recurrence
Salvatore Torquato	Reformulation of the Covering and Quantizer Problems as Ground States of Interacting Particles
Florian Theil	Periodic minimizers in three dimensions
David de Laat	Energy minimization via moment hierarchies
Paolo Piovano	Wulff shape and isoperimetric characterization of crystals
Dmitriy Khavinson	Selected question for polynomials in one and several complex variables
Sergiy Borodachov	Asymptotic Results on the Discrete Riesz Minimal Energy and Polarization Problems when the Power of the Potential Equals the Dimension of the Conductor
Natalia Zoriĭ	Minimum Riesz energy problems for a condenser with "'touching plates"'
Robert Kusner	Möbius energy of Hopf lins in S^3 and Coulomb electrons on S^2
Ulisse Stefanelli	Carbon geometries as optimal configurations
Wei-Hsuan Yu	Two-distance tight frames

Second Workshop: Sphere Packings, Lattices, and Designs, October 27 – 31, 2014:

Eiichi Bannai	Tight Euclidean $t-$designs and tight relative $t-$designs in certain association schemes
Etsuko Bannai	Tight Euclidean $t-$designs on two concentric spheres
Ziqing Xiang	Tight block designs
Fernando Oliveira Filho	Optimization methods for packing problems
Wöden Kusner	A brief analysis of packing regular pentagons in the plane
Yoav Kallus	High-dimensional random packing lattices: Bravais new world
Gabriele Nebe	Automorphisms of extremal lattices
Jingguo Bi	Sub-Linear Root Detection for Sparse Polynomials Over Finite Fields
Giovanni Lazzarini	Spherical designs and height function of lattices
Renaud Coulangeon	Computing unit groups of maximal orders using Voronoi algorithm
Peter Gruber	On Voronoi type results and problems for lattice packings and kissing numbers
Mathieu Dutour Sikiric	Practical Computing of Hecke operators
Oleg Musin	Extreme problems of sphere packings and irreducible contract graphs
Wei-Hsuan Yu	New bounds spherical two-distance sets and equiangular line sets
Peter Boyvalenkov	Upper and lower bounds for potential energy of spherical designs
Maya Stoyanova	Computational algorithms for bounding potential energy of spherical codes and designs
Martin Ehler	Designs in unions of Grassmannians
Romanos Malikiosis	Full spark Gabor Frames in Finite Dimensions
Karlheinz Gröchenig	A packing problem in time-frequency analysis
Lenny Fukshansky	Well-rounded lattices from algebraic constructions
Peter Zeiner	Well-rounded sublattices in the plane
Juan Pablo Rossetti	Integral Lattices, the isospectral problem and the norm one
Yan Zhu	Tight relative 2-designs on two shells in Johnson association schemes
Andriy Bondarenko	Strongly regular graphs in metric geometry
Michael Shub	Well-conditioned Polynomials
Sinai Robins	Cone theta functions and rational volumes of spherical polytopes

Preprints contributed:

Laurent Bétermin, Peng Zhang, *Minimization of energy per particle among Bravais lattices in R^2 : Lennard-Jones and Thomas-Fermi cases*, `arXiv:1402.2751`, BGS.

Laurent Bétermin, *Renormalized Energy and Asymptotic Expansion of Optimal Logarithmic Energy on the Sphere*, `arXiv:1404.4485`, BGS.

Invited scientists:

Moritz Antlanger, Christine Bachoc, Eiichi Bannai, Etsuko Bannai, Carlos Beltrán, Sören Lennart Berg, Laurent Bétermin, Jingguo Bi, Dmytro Bilyk, Andriy Bondarenko, Sergiy Borodachov, Mikhail Bouniaev, Peter Boyvalenkov, Johann Brauchart, Henry Cohn, Renaud Coulangeon, David de Laat, Fernando de Oliveira Filho, Josef Dick, Peter Dragnev, Mitia Duerinckx, Mathieu Dutour Sikiric, Martin Ehler, Markus Faulhuber, Gero Fendler, Erik Friese, Lenny Fukshansky, Peter Grabner, Karlheinz Gröchenig, Peter Gruber, Doug Hardin, Martin Henk, Aicke Hinrichs, Gerhard Kahl, Yoav Kallus, Dmitry Khavinson, Tamás Korodi, Peter Kritzer, Robert Kusner, Wöden Kusner, Giovanni Lazzarini, Paul Leopardi, Romanos Malikiosis, Lev Markhasin, Jordi Marzo, Timothy Michaels, Oleg Musin, Francis Narcowich, Gabriele Nebe, Anton Nikitenko, Braxton Osting, Friedrich Pillichshammer, Paolo Piovano, Danylo Radchenko, Maren Helene Ring, Sinai Robins, Juan Pablo Rossetti, Ed Saff, Ladislav Samaj, Rudolf Scharlau, Achill Schürmann, Sylvia Serfaty, Michael Shub, Brian Simanek, Ian Sloan, Ulisse Stefanelli, Kenneth Stolarsky, Maya Stoyanova, Yujian Su, Xingping Sun, Xun Sun, Florian Theil, Robert Tichy, Salvatore Torquato, Khang Tran, Emmanuel Trizac, Mario Ullrich, Frank Vallentin, Maryna Viazovska, Oleksandr Vlasiuk, Johannes Wallner, Yuguang Wang, Joe Ward, Ziqing Xiang, Wei-Hsuan Yu, Peter Zeiner, Yan Zhu, Marc Zimmermann, Natalia Zoriǐ.

Workshops organized independently of the Main Programmes

Time-frequency Analysis (follow-up workshop)

Organizers: Hans G. Feichtinger (U of Vienna), Karlheinz Gröchenig (U of Vienna)

Dates: January 13 – 17, 2014

Budget: ESI € 8 000.

Report on the workshop

The goal of the workshop was to survey the state-of-the-art of time-frequency analysis and to explore new directions. Contemporary time-frequency analysis covers many different directions in mathematics, with topics as diverse as operator theory and the signal processing of music signals.

The workshop has focused on the following topics of current interest:

1. Gabor frames and their fine structure;
2. Adaptive time-frequency expansions;
3. The time-frequency analysis of Fourier integral operators, Schrödinger equations;
4. Frames obtained from integrable group representations and coorbit theory.

Activities

The workshop was structured in five days - each day 4 to 5 talks of 50 minutes.

Specific information on the workshop

This was a follow-up workshop on the special semester on Time-Frequency Analysis organized at the ESI in the autumn of 2012 by the same organizers. They invited particularly active members and colleagues representing new directions in the field to share their experiences and to contribute to the discussion on the future development of the field, which is gaining more and more momentum in these years.

Outcomes and achievements

The workshop has inspired several of the participants to further discuss open problems in Time-Frequency Analysis and to reach out into new fields linked to time-frequency analysis, e.g. via similar ideas or the use of related mathematical methods.

As after the previous Special Semester (2012) at the ESI, the general feedback from the participants was very good. Most of them have emphasized the stimulating atmosphere and the variety of talks presented during the workshop. They have also acknowledged gratefulness to the ESI as an institution which allowed them to meet and concentrate on the development of new ideas trough intensive discussions with colleagues from different research institutions and countries.

List of talks

Philippe Jaming	A dynamical system approach to Heisenberg Uniqueness Pairs
Qiyu Sun	The abc-problems for Gabor system
Joachim Stoeckler	Gabor frames of totally positive functions and splines
Massimo Fornasier	Consistency of probability measure quantization by means of power repulsion-attraction potentials
Stephan Dahlke	Shearlet Coorbit Spaces: General Setting, Group Theoretical Background, Trace, and Embeddings
Philipp Grohs	Ridgelet Discretization of Linear Transport Equations
Hartmut Führ	Wavelet coorbit theory in higher dimensions
Margit Pap	Fundamental analytic wavelet system for the disc algebra of the unit disc
Filippo De Mari	Coorbit spaces with voice in a Frèchet space
Elena Cordero	Time-frequency analysis of Schrödinger equations with bounded potentials
Ville Turunen	Born-Jordan transform
Jose Luis Romero	Deformation of Gabor systems
Basarab Matei	Sets of Stable Sampling: Construction and Counter-Examples
Isaac Pesenson	Space-frequency localized frames on Riemannian manifolds
Wolfram Bauer	Heat flow and Berezin-Toeplitz calculus
Yurii Lyubarskii	On bandlimited Lipschitz functions
Joaquim Ortega Cerdá	Sampling polynomials in R^n
Helmut Harbrecht	Adaptive Wavelet Boundary Element Methods
Gerard Kerkyacharian	Regularity of Gaussian processes in a geometrical framework
Hutnik Ondrej	Wavelets, analytic function spaces and Toeplitz operators

Publications and preprints contributed:

- Maarten V. de Hoop, Karlheinz Gröchenig and José Luis Romero: Exact and approximate expansions with pure Gaussian wave packets. SIAM J. Math. Anal., Vol.46 No.3, (2014) p.2229-2253.
- Elena Cordero, Karlheinz Gröchenig; Fabio Nicola, Luigi Rodino: Generalized Metaplectic Operators and the Schrödinger Equation with a Potential in the Sjoestrand Class. J. Math. Phys. 55, 081506 (2014); doi: 10.1063/1.4892459.
- Philippe Jaming and Karim Kellay: A dynamical system approach to Heisenberg uniqueness pairs. To appear in J. Anal. Mathem.
- Ondrej Hutnik, Egor A. Maximenko and Anna Miskova: Toeplitz localization operators: Spectral function density. Submitted.
- Margit Pap: A special voice transform, analytic wavelets and Zernike functions; survey paper (60 p.), Advances in Imaging and Electron Physics. Vol 188, 2015.
- Hans G. Feichtinger, Krzystof Nowak and Margit Pap: Asymptotic boundary forms for tight Gabor frames and lattice localization domains, 33 pages (March 2015).
- Isaac Pesenson, Hans Feichtinger, Hartmut Führ: Geometric space-frequency analysis on manifolds, 43 pages (March 2015).
- Alexander Borichev, Yura Lyubarskii: Frame constants near critical density for irregular Gaussian Gabor frames.

Invited scientists:

Wolfram Bauer, Dominik Bayer, Elena Cordero, Stephan Dahlke, Maurice de Gosson, Filipo De Mari, Martin Ehler, Hans-Georg Feichtinger, Gero Fendler, Massimo Fornasier, Hartmut Führ, Karlheinz Gröchenig, Phillip Grohs, Helmut Harbrecht, Ondrey Hutnik, Philippe Jaming, Gerard Kerkyacharian, Andreas Klotz, Yura Lyubarskii, Basarab Matei, Joaquim Ortega-Cerda, Margit Pap, Isaac Pesenson, José Luis Romero, Joachim Stöckler, Qiyu Sun, Ville Turunen.

4th Central European Relativity Seminar

Organizers: Lars Andersson (Albert Einstein Institute (AEI), Golm), Robert Beig (U of Vienna), Piotr Bizon (Jagiellonian U, Cracow), Piotr T. Chruściel (U of Vienna), Helmut Friedrich (AEI, Golm)

Dates: February 27 – March 1, 2014

Budget: ESI € 2 800.

Report on the workshop

The seminar's topic was mathematical general relativity. This was the fourth seminar of a series, which was initiated at ESI January 27 - 29, 2011 (followed by a seminar in Cracow February 2 - 4, 2012, and one in Golm February 7 - 9, 2013).

The series of seminars is designed to provide a forum for younger researchers to present their work, and to expand their research horizons. The anticipated geographical basin of attraction is Austria, Czech Republic, Hungary, Poland and Germany, though this year we also had one colleague from Edinburgh, one from Zagreb, and one from Paris.

Activities

In the main programme there were 28 talks, all given by graduate students and post-docs. We were pleased to have four female speakers in the seminar, with particularly noteworthy talks by Cécile Huneau (ENS, Paris) about the "Construction of general relativistic initial data sets with translational symmetry", and by Annegret Burtscher (U Vienna) on self-gravitating collapse of compressible matter. Both talks described the results obtained during work on both author's remarkable PhD theses. Further, Anna Sakovich (AEI) presented her results on solutions of Jang's equation on asymptotically hyperbolic manifolds, while Jinhua Wang (AEI) described her construction of impulsive wave solutions for nonlinear wave equations satisfying Klainerman's null condition. Particularly interesting talks were also given by Michał Kahl (Jagiellonian U, Cracow) on wave maps on wormholes, by Ivica Smolić (U Zagreb) on Chern-Simons-type theories of gravitation', and by Mikołaj Korzyński (U Warsaw) on using black holes to model inhomogeneities in cosmology.

Specific information on the programme

The seminar was attended by 59 participants, among which 16 were from Vienna (more precisely, 7 researchers and 9 students and graduate students).

We took the opportunity of the event to organize an evening to mark the retirement, in September 2013, of one of the organizers, Prof. Robert Beig from the University of Vienna. The evening was well attended by the participants of the seminar as well as by colleagues from the Physics Department of the University of Vienna, with interesting talks given by Helmut Friedrich (AEI) and the retiree.

Outcomes and achievements

We believe that the event was a success, allowing young researchers to exchange ideas in the studious atmosphere of the Schrödinger Institute. The next seminar of the series will take place in February 2015 in Budapest.

Invited scientists:

Hartmut Abele, Peter Christian Aichelburg, Lars Andersson, Thomas Bäckdahl, Herbert Balasin, Daniel Barta, Robert Beig, Piotr Bizoń, Norbert Bodendorfer, Annegret Burtscher, Piotr Chruściel, Georgios Doulis, David Fajman, Guyla Fodor, Helmut Friedrich, Aleksander Garus, James Grant, David Hilditch, Albert Huber, Cécile Huneau, Michael Hörzinger, Joanna Jalmuzna, Jeremy Joudioux, Michal Kahl, Alicja Konieczny, Mikolaj Korzynski, Klaus Kröncke, Andras Laszlo, Alexander Lecke, Tomas Ledvinka, Patryk Mach, Maciej Maliborski, Sebastian Moeckel, Mate Ferenc Nagy-Egri, Andrzej Odrzywolek, Tim-Torben Paetz, Claudio Paganini, Rodrigo Panosso-Macedo, Michal Piróg, István Rácz, Martin Reiris, Andrzej Rostworowski, Helmut Rumpf, Anna Sakovich, Clemens Sämann, Christian Schell, Martin Scholtz, Walter Simon, Ivica Smolic, Milena Stojković, Robert Svarc, Jedrzej Swiezewski, Sebastian Szybka, Roger Tagne Wafo, Maximilian Thaller, Gabor Zoltan Toth, Matyas Vasuth, Jinhua Wang, Michal Wyrebowski.

Geometry of Computation in Groups

Organizers: Goulnara Arzhantseva (U Vienna), Olga Kharlampovich (Hunter College, New York), Alexei Miasnikov (Stevens Institute of Technology, Hoboken)

Dates: March 31 – April 13, 2014

Budget: ESI € 16 720,
European Research Council (ERC) Grant (€ 3 006,62) and start-up funds (€ 252,51) of G. Arzhantseva.

Report on the workshop

During these two weeks research activity we have brought together researchers interested in residually finite groups and various geometric aspects of computation with infinite groups. They have included specialists in geometric group theory, operator algebras, symbolic dynamics, and low-dimensional topology. In recent years there was a spectacular boost of interaction between these areas, and mathematicians working in different fields have required such an international event to satisfy their common interest.

At the workshop, we presented a unified view on the actual state of art in algorithmic aspects of discrete groups. This stimulated an exchange of ideas and promoted collaboration between the participants. The workshop programme included 4 series of mini-courses. They were aimed at the audience having no prior background in that field and have attracted the interest of algebraists, logicians, and geometers as well as of many students in these areas.

– Minicourse I, Geometry of residually finite groups: Isomorphism problems by **Martin Bridson (Oxford)**;

– Minicourse II, Geometry of residually finite groups: Exotic residually finite groups by **Alexei Miasnikov (Hoboken)**;

– Minicourse III, Introduction to the space of marked groups: Fixed point properties by **Yves de Cornulier (Paris-Orsay)**;

– Minicourse IV, Introduction to the space of marked groups: Limits of hyperbolic groups by **Vincent Guirardel (Rennes)**.

The minicourses lectures and workshop talks have been complemented by numerous informal blackboard sessions, and many team and pairwise discussions. There were even two additional informal mini-courses following the requests of several participants: on the "Combination theorems for Gromov hyperbolic groups" by **Olga Kharlampovich (New York)** and on the "Isoperimetric function of one-relator groups" by **Arye Juchasz (Haifa).**

Our research event at the ESI has attracted many young mathematicians ($\sim 45\%$) and world wide experts from diverse research areas of modern group theory and related fields. It was well attended by many local scientists from different research institutions, e.g. from the Faculty of Mathematics of U Vienna as well as from the Vienna U of Technology.

Specific information on the workshop

Our research at the ESI has included progress on the following topics.

• **Relative hyperbolicity, Γ-limit groups, and graphical small cancellation condition**

We have initiated the study of generic properties of van Kampen diagrams over finite presentations of infinite groups. The ideal would be to get a picture similar to the famous theory of random graphs. It remains to be seen how much can be done here but an initial progress has been done during the workshop.

Vertex and extension finiteness in relatively hyperbolic groups was discussed by **Gilbert Levitt (Caen)**. This is a joint work with **Vincent Guirardel (Rennes)**. He has focused on all splittings of a finitely generated group over subgroups in a fixed family, and has discussed whether only finitely many vertex groups appear, up to isomorphism. Computational aspects of finitely presented groups have been presented by **Jeremy Macdonald (New York)**. He has considered groups discriminated by hyperbolic, locally quasi-convex, and torsion-free groups and has presented interesting applications of his algorithmic viewpoint to enumeration and algorithmic recognition of such groups. This is a joint work with **Inna Bumagina (Ottawa)**, who has given her own talk on generalizations of several significant algorithmic results on the conjugacy and the conjugacy search problem from Gromov hyperbolic to relatively hyperbolic groups. Her results include a subtle knowledge of complexity issues of these problems. **Olga Kharlampovich (New York)** has presented several joint works with **Alexei Miasnikov (Hoboken)**. She has shown in detail how to work algorithmically with Γ-limit groups for a torsion-free hyperbolic group Γ. **Damian Osajda (Vienna)** has presented his joint work with **Goulnara Arzhantseva (Vienna)** about graphical small cancellation groups. He explained their proof of the Haagerup property (= Gromov's a-T-menability) for finitely generated groups defined by infinite presentations satisfying the graphical small cancellation condition with respect to graphs endowed with a compatible wall structure. Their technique provides many new examples and a general method to show the Haagerup property for graphical small cancellation groups. **Chris Cashen (Vienna)** has presented his joint work with **Goulnara Arzhantseva (Vienna)** and **Jing Tao (Oklahoma)**. They have recently introduced the concept of growth tight actions and have determined two conditions on a group action that guarantee the growth tightness. The first is that the action contains a strongly contracting element, which means that some group element has an axis that behaves like a geodesic in a hyperbolic space. The second is a technical condition that controls how badly the orbit map distorts the group. Their results generalize all previously known growth tightness results for actions of hyperbolic and relatively hyperbolic groups.

• Geometry of residually finite groups

Residually finite groups are among the most studied objects in the theory of infinite groups. They become prominent when Malcev discovered a simple decision algorithm to solve the word problem (WP) in such groups. The algorithm consists of two procedures: the first one solves the "YES" part of WP, by enumerating all possible consequences of the defining relators (null-homotopic words); and the second one, solves the "NO" part of WP by checking that the homomorphic images of a given word w are not equal to 1 in some finite quotient of the group G . To do the "NO" part one needs to enumerate all possible finite quotients of G and to find one when the image of w is non-trivial. For a very long time (up to emergence of the geometric group theory and the Gröbner basic techniques) this was one of the most typical decision algorithms in algebra.The above mentioned mini-courses by Bridson and Miasnikov were on the geometric properties of residually finite groups and their connections with algorithms. In particular, **Alexei Miasnikov (Hoboken)** has discussed decisive results that give a solid foundation for the whole study; they were obtained jointly with Kharlampovich and Sapir.

They show that algorithmic and geometric complexity of the Word Problem in residually finite finitely presented groups can be arbitrarily high. To estimate typical difficulties that arise in the finite quotients test (the "No" algorithm) the following concept is used.

The geometry and algorithmic properties of the group G as above depend on the set of all (up to isomorphism) finite quotients of G, the *genus* $\mathcal{F}(G)$ of G. One of the most intriguing directions of research in this area is to relate the geometry of G with $\mathcal{F}(G)$ and to study how the finite index subgroups sit inside G. There is a lot of connections here with recent works of Lubotzky, Segal, Nikolov, Kassabov and others.

Alexei Miasnikov (Hoboken) was also talking about his results with **Denis Osin (Vanderlbit)** on algorithmically finite groups. A group G is algorithmically finite if no algorithm can produce an infinite set of pairwise distinct elements of G. They construct examples of recursively presented infinite algorithmically finite groups and study their properties. **Martin Bridson (Oxford)** reported on the joint work with **Henry Wilton (Cambridge)** on profinite isomorphism problems. They prove that there is no algorithm that, given an arbitrary pair of finitely presented residually finite groups, can determine whether or not the associated map of profinite completions is an isomorphism. Nor do there exist algorithms that can decide whether the associated map is surjective, or whether the profinite completions are isomorphic.

• The space of marked groups.

Two mini-courses were devoted to this subject. **Yves de Cornulier (Paris-Orsay)** introduced the space of marked groups. This is a compact topology on the set of groups endowed with a finite generating family. An important feature of this topology is that the neighborhood of a given marked group only depends on the isomorphism class of the underlying group. He addressed various fixed point properties: it is natural to ask whether a the negation of such a property is a closed property in the space of groups. For instance, Gromov proved that if (X) is a class of metric spaces closed under scaling ultralimits, then the class of groups having a fixed-point-free action on some metric space in (X) is closed in the space of marked groups. **Vincent Guirardel (Rennes)** looked at limits of hyperbolic groups in the space of marked groups from two points of view. If we look at the set of groups that are accumulations of hyperbolic groups, then most such groups are rather wild. But if we fix a hyperbolic group Γ (the free group will be our preferred example), and look at all groups obtained at the limit by varying the generating systems of this fixed group, we obtain Γ-limit groups. The class of these limit groups is quite tame, in contrast to the first situation. By a Kharlampovich–Miasnikov's result, all finitely generated Γ-limit groups are subgroups of iterated centralizer extensions. If Γ is a free group, then by the results of Guirardel G is a Γ-limit group if and only if it is an iterated a generalized double. **Nikolay Romanovskiy (Novosibirsk)** presented an introduction to model theory for rigid solvable groups. He also explained his recent results on rigid groups, some of them joint with **Alexei Miasnikov (Hoboken)**. **Alexander Taam (New York)** and **Olga Kharlampovich (New York)** proved that every Γ-limit group for a torsion-free hyperbolic group Γ is an iterated double. This is an analogue of V. Guirardel's result for free groups described in his mini-course.

• Geometric and asymptotic properties of free groups

Alexander Olshanskii (Nashville) has discussed his recent results on growth and cogrowth of subgroups in free groups. In particular, he formulated theorems on the actions of maximal growth and on pairs of finitely generated subgroups in free groups. **Zoran Sunic (College Station)** utilized a criterion for the existence of a free subgroup acting freely on at least one of its orbits to construct such actions of the free group on the circle and on the line, leading to orders on free groups that are particularly easy to state and work with. The dynamical realization of the obtained orders is very flexible and allows for modifications, which yield Cantor sets of orders on the free group. He also obtained a restatement of the orders in terms of certain quasi-characters of free groups. **François Dahmani (Grenoble)** studied isomorphisms between semi direct product with Z, that are hyperbolic, or relatively hyperbolic of a certain kind. He investigated the conjugacy problem for some outer automorphisms of a free group. A main tool is to understand some orbit problem by considering the relevant JSJ decomposition. Another tool is the body of works on the isomorphism problem in different contexts in the presence of negative curvature. **Goulnara Arzhantseva (Vienna)** and **Damian Osajda (Vienna)** have checked that the famous Lyndon free group has several analytic properties such as the Haagerup property. It follows, in particular, that the strong Baum-Connes conjecture holds for this group.

• Complexity, computability, and metric approximations

Markus Lohrey (Leipzig) discussed parallel complexity of the compressed word problem in groups. **Paul Schupp (Urbana)** explained how the asymptotic-generic point of view of geometric group theory has led to the development of a new area of computability theory. **Bob Gilman (New York)** presented a survey on recent results on the unsolvability of decision problems for finitely presented groups prefigured a strong connection between combinatorial group theory and complexity theory.

John S. Wilson (Oxford) reported on current joint work with **Andreas Thom (Dresden)** on the topological and algebraic properties of metric ultraproducts of finite simple groups. **Swiatoslaw Gal (Wroclaw)** talked on groups generated by finite set of transformations and bi-invariant metrics. Such metrics are crucial in the study of metric approximations of discrete groups such as sofic and hyperlinear approximations. **Jakub Gismatulin (Wroclaw)** presented his very recent results on weak sofic and weak hyperlinear groups. **Alina Vdovina (Newcastle)** presented her construction of trivalent expanders. **Laszlo Pyber (Budapest)** discussed in detail the Product theorem for finite simple groups and its applications to the construction of expanders and more.

List of talks

Gilbert Levitt	Vertex and extension finiteness in relatively hyperbolic groups
Jeremy Macdonald	Effective coherence, discrimination, and quasi-convexity
Christopher Cashen	Growth tight actions
Inna Bumagina	The conjugacy and the conjugacy search problem in relatively hyperbolic groups
Alexander Olshanskii	Growth and cogrowth in free groups
Zoran Sunic	Free groups: from free actions to orders to quasi-characters
Martin Bridson	Geometry of residually finite groups: Profinite isomorphism problems (2 talks)
Yves Cornulier	Introduction to the space of marked groups: Fixed point properties (2 talks)
Markus Lohrey	Parallel complexity of the compressed word problem in groups
Paul Schupp	Asymptotic properties of computability
Bob Gilman	Groups and complexity theory
Damian Osajda	Graphical small cancellation groups with the Haagerup property
Ashot Minasyan	New examples of groups acting on real trees
Alexei Miasnikov	Geometry of residually finite groups: Exotic residually finite groups (2 talks)
Vincent Guirardel	Introduction to the space of marked groups: Limits of hyperbolic groups (2 talks)
Nikolay Romanovskiy	Logical aspects of the theory of rigid solvable groups
John S. Wilson	Metric ultraproducts of finite simple groups
Swiatoslaw Gal	Groups generated by finite set of transformations and biinvariant metrics
Jakub Gismatulin	Approximation of groups by manageable structures - weak sofic and weak hyperlinear groups
Olga Kharlampovich	Some algorithms for Γ-limit groups for a torsion-free hyperbolic group Γ
Alina Vdovina	Trivalent expanders and Riemann surfaces
Laszlo Pyber	Applications of the product theorem
François Dahmani	On the conjugacy problem for some automorphisms of free groups

Publications and preprints contributed

G. Arzhantseva, C. Cashen, J. Tao, *Growth tight actions*, Pacific Journal of Mathematics, (2015), in press. AKM

G. Arzhantseva, M. Steenbock, *Rips construction without unique product*, `arXiv:1407.2441`, AKM

I. Bumagin, *Time complexity of the conjugacy problem in relatively hyperbolic groups*, `arXiv:1407.4528` , AKM.

A. Zakharov, *On the rank of the intersection of free subgroups in virtually free groups*, Journal of Algebra 418 (2014), 29-43, AKM.

C. Cashen, G. Levitt, *Mapping tori of free group automorphisms, and the Bieri-Neumann-Strebel invariant of graphs of groups*, `arXiv:1412.8582`, AKM

C. H. Cashen, J. Tao, *Growth Tight Actions of Product Groups* `arXiv:1404.4335`, AKM.

M. Chiswell, A. M. W. Glass, J. S. Wilson, *Residual nilpotence and ordering in one-relator groups and knot groups*, Math. Proc. Camb. Phil. Soc. (2015), **158**, 275-288, AKM.

A. Martin, M. Steenbock, *Cubulation of small cancellation groups over free products*, `arXiv:1409.3678`, AKM

Invited scientists:

Amina Abdurrahman, Elena Aladova, Goulnara Arzhantseva, Federico Berlai, Martin Bridson, Inna Bumagin, Christopher Cashen, Yu-Yen Chien, Maurice Chiodo, Laura Ciobanu, Francois Dahmani, Yves de Cornulier, Andrew Duncan, Matthew Durham, Elisabeth Fink, Ann-Sofie Fisker, Swiatoslaw R. Gal, Albert Garreta-Fontelles, Robert Gilman, Jakub Gismatullin, Dominik Gruber, Vincent Guirardel, Arye Juhasz, Dmitriy Kagan, Delaram Kahrobaei, Olga Kharlampovich, Gabor Kun, Gilbert Levitt, Markus Lohrey, Alexandre Martin, Jeremy Macdonald, Alexei Miasnikov, Ashot Minasyan, Alexander Ol'shanskiy, Damian Osajda, László Pyber, Nikolay Romanovskiy, Vladimir Shpilrain, Paul Schupp, Markus Steenbock, Zoran Sunić, Alexander Taam, Alexey Talambutsa, Tetsu Toyoda, Alina Vdovina, Enric Ventura, Qin Wang, John Wilson, Alexander Zakharov.

Theoretical and Applied Computational Inverse Problems

Organizers: Liliana Borcea (U of Michigan), Otmar Scherzer (U of Vienna), John C. Schotland (U of Michigan)

Dates: May 5 - 16, 2014

Budget: ESI € 13 120.

Report on the workshop

This workshop has been concerned with recent developments in *Inverse Problems theory* and *applications*. Inverse Problems contain a wide range of applications, such as biological and medical imaging, geophysical prospecting, astronomy and earth sciences, which have all been touched in this workshop.

Three up-to-date research topics that we have been focusing on in this workshop have been:

- *Hybrid Inverse Problems*, where the goal is to identify parameters using *coupled physics* experiments. The catch of these techniques is that excitation (illumination) is converted inside the investigated medium into energy, which provides a secondary source, which can be used for additional parameter identification. The prime examples in this field are Photoacoustics and coupled magnetic resonance imaging. The mathematical challenges in coupled physics imaging are mathematical modeling, asymptotic analysis, and computational solutions. An introductory course on this topic has been given by Simon Arridge (UCL, London).
- *Imaging in Random Media:* There the goal is to taking into account random fluctuations in the background medium when solving inverse problems. The introductory course on this topic has been given by Lenya Ryzhik (Stanford).
- *Computational Inverse Problems:* The inherent instability of inverse problems requires appropriate computational solutions, for direct inversion or appropriate imaging techniques.

The later can be modeled in different ways to provide appropriate access to imaging parameters by asymptotic analysis or indirect imaging data. Direct inversion can be performed with regularization techniques, iterative or variational. This topic was considered in many topics, but was not covered by an introductory course.

This workshop aims of bringing together researchers working in abstract and computational Inverse Problems. Both theoretical foundations, computational aspects, and mathematical modeling of inverse problems are considered in this workshop.

Activities

We had a two weeks workshop. One week was devoted to introductory courses by key persons, which provide introductory lectures to the research in the novel areas. We heard courses from Lenya Ryzhik (Stanford) and Simon Arridge (UCL, London). Gunther Uhlmann had to cancel because of health reasons,

The interdisciplinary nature of the research topic was manifested by inviting also people from Physics who took part in discussion on modeling aspects of hybrid inverse problems and in random media.

Specific information on the programme

The following people associated with the Computational Science Center at U Vienna participated in the workshop.

PhD Students: Guozhi Dong, Thomas Glatz, Clemens Kirisits, Lukas Lang, José A. Iglesias Martinez, Wolf Naetar, Aniello Raffaele Patrone, Cong Shi, Julian Schmid, Thomas Widlak.

Post Doctoral Researchers: Peter Elbau, Daniel Leitner, Leonidas Mindrinos, Stefania Tron.

Outcomes and achievements

John Schotland collaborated with Shari Moskow on topological reduction of the inverse Born series. He also collaborated with Liliana Borcea on quantum inverse source problems in random media. In both cases, promising results were obtained that will be reported in future publications.

Otmar Scherzer initiated a collaboration with Chrysola Tsogka on photo acoustic imaging in random media. He also collaborated with Maarten de Hoop on stability estimates in inverse scattering which have been reported in

- E. Beretta, M. V. de Hoop, L. Qiu, and O. Scherzer, *Inverse boundary value problem for the Helmholtz equation: Multi-level approach and iterative reconstruction.* Preprint on ArXiv, arXiv:1406.2391, University of Vienna, Austria, 2014.

Liliana Borcea started a collaborative project with Lenya Ryzhik and Alexei Novikov on the analysis of electromagnetic wave propagation, in the paraxial regime, in random media with long range correlation. She also collaborated with Vladimir Druskin and Alexei Novikov on a model reduction approach to solving inverse problems for parabolic equations. Moreover, she collaborated with Ricardo Alonso on a project on robust transport based imaging with incoherent waves in random waveguides.

ESI will be acknowledged in any publications resulting from the above collaborations.

List of talks

First Workshop, May 5 – 9, 2014

Lenya Ryzhik	Waves in weakly random media I
Lenya Ryzhik	Waves in weakly random media II
Lauri Oksanen	Computational Approaches to the Boundary Control Method
Peter Elbau	A Model for Photoacoustic Sectional Imaging
Lenya Ryzhik	Waves in weakly random media III
Lenya Ryzhik	Waves in weakly random media IV
Joselin Garnier	Correlation-based imaging with moving sensors
Thomas Widlak	Stability in linearized elastography
Chrysoula Tsogka	Signal to Noise Ratio analysis in passive correlation based imaging
Lenya Ryzhik	Kinetic models for waves in random media
Simon Arridge	Diffuse Optical and PhotoAcoustic Tomography
Simon Arridge	Reconstruction in PhotoAcoustic Tomography I
Simon Arridge	Reconstruction in PhotoAcoustic Tomography II
Alexander Mamonov	Krein-Gelfand-Levitan algorithm for inverse hyperbolic problems via spectrally matched finite-difference grids
Maarten de Hoop	Inverse problem of electroseismic conversion
Wolf Naetar	Quantitative photoacoustic tomography with piecewise constant material parameters
Stefan Rotter	Controlling waves in complex scattering systems

Second Workshop, May 12 – 16, 2014

Martin Hanke	Multi frequency MUSIC for impedance imaging
Plamen Stefanov	Traveltime tomography with partial data
Habib Ammari	Emerging imaging approaches in medicine
Roman Andreev	On simultaneous flux/source identification
Miguel Moscoso	Imaging with sparsity promoting optimization
Liliana Borcea	Imaging in complex environments
Alexei Novikov	Imaging of sparse scatterers
Konstantinos Kalimeris	Attenuating models and reconstruction methods in Photoacoustic Imaging
Barbara Kaltenbacher	Regularization by discretization: recent convergence results and multilevel strategies
Vladimir Druskin	Finite-difference Gaussian quadrature rules for Dirichlet-to-Neumann Operators and inverse problems
Ricardo Alonso	Electromagnetic wave propagation in random waveguides
Ronny Ramlau	Inverse Problems in Adaptive Optics
Alexandru C. Tamasan	Uniqueness and nonuniqueness in Current Density Impedance Imaging with one current density information
Shari Moskow	Inverse Born series for the Calderon problem and related inverse problems
John C. Schotland	Acousto-Optic Imaging

Preprints contributed:

- E. Beretta, M. V. de Hoop, L. Qiu, and O. Scherzer, *Inverse boundary value problem for the Helmholtz equation: Multi-level approach and iterative reconstruction.* Preprint on ArXiv, arXiv:1406.2391, University of Vienna, Austria, 2014.

Invited scientists:

Ricardo Alonso, Habib Ammari, Roman Andreev, Simon Arridge, Zakaria Belhachmi, Liliana Borcea, Maarten de Hoop, Vladimir Druskin, Guozhi Dong, Peter Elbau, Josselin Garnier, Martin Hanke-Bourgeois, Manas Kar, Barbara Kaltenbacher, Konstantinos Kalimeris, Rajesh Kumar, Ankik Kumar Giri, Alexander Mamonov, José A. Iglesias Martinez, Leonidas Mindrinos, Miguel Moscoso, Shari Moskow, Wolf Naetar, Alexei Novikov, Lauri Oksanen, Christiane Pöschl, Ronny Ramlau, Stefan Rotter, Leonid Ryzhik, Otmar Scherzer, John C. Schotland, Cong Shi, Plamen Stefanov, Alexandru C. Tamasan, Chrysoula Tsogka.

Algebraic Quantum Field Theory: Its Status and Its Future

Organizers: Romeo Brunetti (U Trento), Claudio Dappiaggi (U Pavia), Klaus Fredenhagen (U Hamburg), Jakob Yngvason (U of Vienna)

Dates: May 19 – 23, 2014

Budget: ESI € 13 440.

Report on the workshop

The algebraic approach to quantum field theory (AQFT) is a well-established branch of mathematical physics which emphasizes the role of observables and their interplay with the notion of locality and causality. From a physical point of view, it provides a very effective axiomatic framework and it has the net advantage of being essentially the only procedure which can be naturally applied when the underlying background is curved. Although it exists since more than fifty years, we can safely claim that this field of expertise is witnessing a period of renaissance. New results and applications have become available thanks to the work of different research groups and, in turn, this burst of activities is attracting several new students who are interested in pursuing a research career in algebraic quantum field theory.

Manifolds were the goals of the workshop: On the one hand the aim was to capitalize on these recent successes by bringing together both the more renown scientists working in algebraic quantum field theory and some of the younger PhD students and post-doc fellows, in order to discuss their recent findings. On the other hand, we want to avoid an excessive dispersion of our limited forces. The tendency of focusing only on its own research project ignoring the advances in close-by fields has to be avoided at all costs. A week of scientific discussions and a long list of talks, covering most of the recent trends in algebraic quantum field theory, was aimed at facilitating the exchange of information and the rise of new collaborations.

Activities

The workshop was held from May 19 to May 23, 2014. There were over 60 invitees coming mostly from Europe, but also from Japan, the USA and Brazil. The participants were roughly divided in half between senior staff members and younger scientists, such as PhD students and post-doc fellows.

During the whole week we planned 32 talks, 7 per days with the exception of Friday when we had only 4 talks in order both to leave the afternoon of the last day free for discussions and to avoid the usual problem that there are not many people attending the talks during the last afternoon since many already leave to travel back home. The speakers included both senior scientists, post-docs and PhD students.

The planning of the talks was organized in such a way that each day covered one of the main thematic areas in which AQFT has seen progresses in the last years. It is also noteworthy both that the programme of Wednesday was dedicated to the upcoming seventieth birthday of Professor Detlev Buchholz and that, in addition, some time for in-depth discussions had been allocated.

Specific information on the workshop

As we have already written above, the goal of the programme was to give a bird view of several recent hot topics in algebraic quantum field theory. Although we cannot enter in the details of all talks, we can certainly indicate three key themes which have been thoroughly discussed during the workshop:

- Both in perturbative algebraic quantum field theory and in classical field theory it has been advocated that the main role is played by algebras of functionals over sets of field configurations on globally hyperbolic spacetimes. Hence the approach is local and functorial, being characterized by a combination of geometric, analytic and algebraic elements. Due to its relative novelty, both its structural properties and its applications to concrete models have been discussed by different speakers.
- In the framework of algebraic quantum field theory, a longstanding open issue has been the implementation of local gauge invariance. Recently several research groups started to tackle this problem from different perspectives and some speakers reported their findings. Without entering into the details of the talks, we stress that on the one hand, techniques, used in theoretical physics since many years, such as the BRST and the Batalin-Vilkovisky quantization, have been now put on solid grounds also in the context of algebraic quantum field theory. On the other hand, if one focuses on simple cases, such as Abelian gauge theories, it appears that they do not abide to the principle of general local covariance, one of the guiding principle of the modern approach to AQFT. We remark also that the research efforts have not only been focused on the algebraic side of gauge theories, but also on the identification of quantum states for gauge theories of Yang-Mills type which are of Hadamard form.
- Another key open issue in the framework of algebraic quantum field theory is the construction of interacting models. A recent approach, which gives a solution in certain specific contexts, is based on the deformation of a C*-dynamical system, associated to a free field theory, into that of an interacting theory via a procedure called warped convolution. As it has been explained during the workshop, the interest towards this approach is manifold: On the one hand it allows also to construct non linear sigma models and, on the other hand, it is closely connected to models of non-commutative field theories.

Outcomes and achievements

Overall the workshop met its original goal, namely it has stimulated an exchange of ideas and promoted collaborations between people working in different groups and research areas within AQFT. It is noteworthy that all talks were followed by several questions aimed at better understanding the existence of connections between different approaches and results. Topics like the implementation of interactions via the so-called perturbative algebraic quantum field theory, the construction of integrable and sigma models via deformation techniques or the validity of the principle of general local covariance in presence of local gauge symmetries have caught the attention of many participants. Several interesting discussion groups were formed and it is foreseeable that new results and publications will be ready in the next few months. In view also of the comments, we received from many participants, the workshop was a complete success in catching the attention, especially of the younger students, towards the several remaining open problems in algebraic quantum field theory.

List of talks

Workshop, May 19 – 24. 2014

Sabina Alazzawi	Construction of O(N)-invariant nonlinear sigma-models
Marco Benini	Optimal observables for gauge theories via cohomology with restricted support
Christian Brouder	On the main operations with distributions having a specified wavefront set
Detlev Buchholz	The quest for understanding in quantum field theory: A new perspective
Giovanni Collini	Fedosov quantization and Quantum Field Theory
Yoann Dabrowski	Functional analytic properties of generalized Hormander spaces of distributions and generalized spaces of microcausal functionals
Michael Duetsch	Massive vector bosons: is the geometrical interpretation as a spontaneously broken gauge theory possible at all scales?
Chris Fewster	Algebraic quantum field theory in curved spacetimes
Christian Gérard	Construction of Hadamard states for linearized Yang-Mills equations II
Thomas-Paul Hack	Quantization of the linearised Einstein-Klein-Gordon system on arbitrary backgrounds and the special case of perturbations in Inflation
Jan Holland	Operator Product Expansion Algebra II
Stephan Hollands	Operator Product Expansion Algebra I
Igor Khavkine	The Calabi complex: a case study in linear dynamical obstructions to isotony
Benjamin Lang	Twisted Quantum Fields in Curved Spacetimes á la C.J. Isham from the point of view of Algebraic Quantum Field Theory
Gandalf Lechner	Localization in Nets of Standard Spaces
Roberto Longo	Noncommutative Geometrical Aspects in Conformal Nets
Pierre Martinetti	Grand symmetry spectral action and the Higgs mass
Davide Pastorello	Geometric Hamiltonian formulation of Quantum Mechanics on complex projective spaces
Giuseppe Ruzzi	Nets of local algebras and gauge theories
Ko Sanders	Understanding free electromagnetism in the light of general covariance
Nicola Pinamonti	Influence of quantum matter fluctuations on the expansion parameter of timelike geodesics
Karl-Henning Rehren	Boundary conditions and gauge transformations
Kasia Rejzner	Perturbative algebraic quantum field theory: recent results and new perspectives
Pedro Lauridsen Ribeiro	Causal Wedges: a General Framework
Alexander Schenkel	Abelian quantum gauge theories via differential cohomology
Jan Schlemmer	Towards covariant adiabatic renormalization on crossed product spaces
Daniel Siemssen	Global Existence of Solutions of the Semiclassical Einstein Equation on Cosmological Spacetimes
Yoh Tanimoto	Wedge-local fields in integrable models with bound states
Gennaro Tedesco	Multi-local transformations for Fermi fields on the circle
Michał Wrochna	Construction of Hadamard states for linearized Yang-Mills equations I
Rainer Verch	Hadamard condition, ”local vacuum (S-J) states” and Wick-products
Jochen Zahn	Locally covariant charged fields

Invited scientists:

Sabina Alazzawi, Dorothea Bahns, Marco Benini, Marcel Bischoff, Henning Bostelmann, Volker Branding, Jacques Bros, Christian Brouder, Romeo Brunetti, Detlev Buchholz, Daniela Cadamuro, Alan Carey, Piotr Chruściel, Fabio Ciolli, Giovanni Collini, Yoann Dabrowski, Claudio Dappiaggi, Sergio Doplicher, Michael Dütsch, Henri Epstein, Davide Fermi, Chris Fewster, Klaus Fredenhagen, Christian Gérard, Luca Giorgetti, Michael Gransee, Thomas-Paul Hack, Florian Hanisch, Jan Holland, Stefan Hollands, Albert Huber, Igor Khavkine, Christian Köhler, Benjamin Lang, Pedro Lauridsen Ribeiro, Gandalf Lechner, Roberto Longo, Umberto Lupo, Mathias Makedonski, Pierre Martinetti, Ugo Moschella, Albert Georg Passegger, Davide Pastorello, Nicola Pinamonti, Matthias Plaschke, Sebastian Poscher, Karl-Henning Rehren, Katharina Rejzner, Giuseppe Ruzzi, Ko Sanders, Alexander Schenkel, Jan Schlemmer, Daniel Siemssen, Michael Stiller, Yoh Tanimoto, Mojtaba Taslimitehrani, Gennaro Tedesco, Rainer Verch, Michal Wrochna, Jakob Yngvason, Jochen Zahn.

ESI-EMS-IAMP Summer School on Mathematical Relativity: 99 Years of General Relativity

Organizers: Robert Beig and Piotr T. Chruściel (U Vienna), Mihalis Dafermos (U Princeton), Helmut Friedrich (AEI Golm), Gregory Galloway (U Miami), Richard M. Schoen (U Stanford)

Dates: July 28 - August 1, 2014

Budget: ESI € 14 837,
European Mathematical Society (EMS) € 4 000, International Associated of Mathematical Physics (IAMP) € 3 000, National Science Foundation (NSF) $ 34 000, American Institute of Physics (AIP) $ 1 000, Classical and Quantum Gravity (CQG) € 500.

The main part of the School's financing (€ 14 837) came from ESI. We are grateful for further financial support to the European Mathematical Society (EMS) who contributed € 4 000 to the budget, to the International Associated of Mathematical Physics (IAMP) for its contribution of € 3 000, and to the National Science Foundation (NSF), who contributed $ 34 000 to the participants' and lecturers' travel expenses through grant DMS-1406614 entitled "Ninety-Nine Years of General Relativity: ESI-EMS-IAMP Summer School on Global Aspects of Mathematical Relativity". Last but not least, we are grateful to the Journal of Mathematical Physics (JMP/AIP) who contributed $ 1 000, and the journal "Classical and Quantum Gravity" (CQG) who contributed € 500 which were used to host a social dinner evening for all participants. We thank all these institutions for their support.

Report on the Summer School

Mathematical general relativity has been the subject of intense studies in recent years, and there has been steadily growing interest in the mathematical community in the topic. On one hand this is driven by the expected direct detection of gravitational waves within the next few years, when the new generation of laser interferometric gravitational observatories will start collecting data. On the other hand there is an intrinsic attraction to the extremely difficult mathematical problems that are steadily being resolved. Examples of outstanding recent achievements in the domain, of highest mathematical difficulty, include the construction of a large class of dynamical black holes by Dafermos, Holzegel and Rodnianski, the construction of a new class of general relativistic initial data sets with no gravitational field outside of conical regions by Carlotto and Schoen, the resolution of the L^2-curvature conjecture by Klainerman, Rodnianski and Szeftel, and the construction of trapped surfaces by focusing gravitational waves by Christodoulou.

The aim of the school was to provide students from all over the world an opportunity to become acquainted with tools needed to study, and further develop, the above, as well as other topics in mathematical general relativity.

Activities

The school started with a very short introduction to some basic concepts of differential geometry (2 hours, R. Beig) and then moved on to an introduction into general relativity (3 hours, M. Mars). These latter lectures both set the scene for the more advanced remaining lectures, but also discussed advanced material like black hole uniqueness theorems and the the positive mass theorem, not covered in other lectures. These remaining lectures comprised four courses of five lectures each: G. Galloway covered Lorentzian causality, a subject of interest in itself, but needed in particular for the evolution problem under the Einstein equations addressed in H. Ringstrom̈’s lectures. After presenting, in his course, the local existence problem for the Einstein equations, Ringström gave a detailed discussion of an instructive PDE for which global stability of the trivial solution can be proved, illustrating the key aspects of the problem at hand. G. Holzegel gave a rather detailed account of the decay of scalar waves on the Schwarzschild spacetimes. These are important ingredients in the ongoing attempts to prove nonlinear stability of the Schwarzschild or Kerr spacetime. The full set of Einstein equations falls into evolution equations and constraint equations, an underdetermined elliptic system which restricts the allowable initial data. That system was derived and studied in the course of J. Corvino, both in the asymptotically flat (’isolated systems’) and compact (’cosmological’) setting. These lectures were complemented by two lectures by S. Gillessen, who presented the state-of-the-art experimental evidence for existence of a black hole in the center of our Galaxies, discussing in detail some of the experimental and theoretical issues that arise.

Despite the unavoidable variations in the amount of detail between and sometimes within lectures, the speakers succeeded in giving attendants an excellent starting point for studying the original literature, to which the lecturers themselves are important contributors.

We are very grateful to the ESI and the remaining sponsors for giving us the opportunity to organize a very successful school, and to the administrative staff of ESI and of the University of Vienna for their efficient help.

Specific information on the Summer School

The participants were chosen from more than 120 qualified applicants from a dedicated web site. Due to the high number of excellent applicants, the lectures were moved from the initially planned ESI lecture hall to the Lise Meitner lecture hall at the Faculty of Physics of University of Vienna, a two minutes walk from ESI’s premises. In order to handle the large number of participants, administrative help was provided by the secretarial staff of the Theory Group of University of Vienna.

Outcomes and achievements

The school was attended by 94 registered participants, 18 of whom were from Austria.

In total there were 17 female and 77 male participants of 22 different nationalities and coming from 18 different countries of residence. The different nationalities of the participants were Austria, Belgium, Brasil, Cameroon, China, Colombia, Croatia, France, Germany, India , Iran, Italy, Lebanon, Mexico, Poland, Portugal, Spain, Sweden, Switzerland, UK, USA, Venezuela.

The various countries of residence participants were coming from were Austria, Belgium, Brasil, Cameroon, Croatia, France, Germany, Iran, Italy, Lebanon, Mexico, Poland, Portugal, Spain, Sweden, Switzerland, UK, USA.

The high number of local participants makes clear the direct benefits of ESI's activities to local students, who had the opportunity to obtain an in-depth introduction to an actively developing scientific area by the world leading experts in the field.

The success of the school is clearly illustrated by the overwhelmingly positive response to an online questionnaire filled out by a majority of participants. The responses to the questionnaire are summarised in an enclosed document.

List of talks

Robert Beig (Vienna)	Introduction to differential geometry
Marc Mars (Salamanca)	Introduction to general relativity
Gregory Galloway (Miami)	Lorentzian causality
Justin Corvino (Lafayette)	Constraint equations
Hans Ringstroem (KTH Stockholm)	The Evolution problem in General Relativity
Gustav Holzegel (Imperial, London)	Wave equations on black hole space-times
Stefan Gillessen (MPI für extraterrestrische Physik, Garching)	The galactic center

Publications and preprints contributed:

P. Suárez-Serrato, R. Torres, *A note on collapse, entropy, and vanishing of the Yamabe invariant of symplectic 4-manifolds*, `arXiv:1408.1586`, Journal of Geometry and Physics, Vol. 86 (2014), pp. 383-391,

R. Torres, *Cauchy surfaces and diffeomorphism types of globally hyperbolic spacetimes* `arXiv:1407.2773`, Class. Quantum Grav. 31 (2014) 175006.

Invited scientists:

Florian Aigner, Guglielmo Albanese, Juan Angel Aledo, Adriana Araujo Salcedo, Phillip Josef Bachler, Moulik K. Balasubramanian, Wasilij Barsukow, Robert Beig, Michael Bell, Mishra Bhupendra, Luca Bonetti, Gerhard Bräunlich, Irene Brito, Annegret Burtscher, Eliana Chaverra, Piotr Chruściel, Nastassja Cipriani, Michael Cole, Justin Corvino, Joana Cristian, Daniel De la Fuente, Adrian del Rio Vega, James Dilts, Max Dohse, Dominic Dold, Krsysztof Drachal, Arash Ghaani Farashahi, Anne Franzen, Gregory Galloway, Edgar Gasperin Garcia, Stefan Gillessen, Karsten Gimre, Andrew Goetz, David Hilditch, Gustav Holzegel, Deanna Hooper, Michael Hörzinger, Ola Hosseiky Malaeb, Adem Hursit, Lukas Ifsits, Sophia Jahns, Joanna Jalmuzna, Christopher Kauffman, Niki Kilbertus, Pascal Kilian, Brian Klatt, Paul Klinger, Klaus Kröncke, Eric Larsson, Adam Layne, Jeremy Leach, Alexander Lecke, Dan Lee, Yihan Li, Eric Ling, Taha Malik, Marc Mars, Govind Menon, Benjamin Mesić, Joao Paulo Morais Graca, Grace Mwakyoma, Anna Nakonieczna, Lukasz Nakonieczny, Pedro Oliveira, Jan Ostrowski, Tim-Torben Paetz, Michael Pinkard, Stefan Pletka, Juan Posso, Bruno Premoselli, Katharina Radermacher, Hans Ringström, Henri Roesch, Rafael Rubio, Philip Schäffer, Juan Jesus Salamanca Jurado, Clemens Sämann, Viraj Sanghai, Jessica Santiago Silva, Oliver Sarbach, Christian Schell, Katarzyna Senger, Ben Sheard, Tomasz Smolka, Jedrzej Swiezewski, Roger Tagne Wafo, Rosemberg Toala Enriquez, Maximilian Thaller, Rafael Torres, Sophie Viaene, Drazen Vrzan, Bo Xia, Wei Yuan, Josef Zehetbauer.

Scaling Limits and Effective Theories in Classical and Quantum Mechanics

Organizers: Chiara Saffirio (U Zürich), Benjamin Schlein (U Zürich), Sergio Simonella (TU Munich), Jakob Yngvason (U Vienna).

Dates: September 22 – 26, 2014

Budget: ESI € 12 640,
European Research Council (ERC) Grant MAQD-240518 (about € 12 000), American Institute of Physics (AIP) $ 1 000.

Report on the workshop

Typical systems of interest in physics, biology and applied sciences can be described by models with a large number of components. The microscopic behavior of such systems is driven by fundamental equations like the Newton or the Schrödinger equation. Because of the huge number of particles, it is usually impossible to solve the fundamental equations and to analyze the system in terms of its elementary components. At the microscopic level, the behavior of the particles appears to be extremely complicated.

On the other hand, observers are interested in the collective behavior of the system, arising on space and time scales which are much larger than the ones characterizing the microscopic dynamics. On such macroscopic scales, the systems appear much simpler, and can be usually described by partial differential equations depending on a small number of degrees of freedom. In certain cases, it has been possible to understand the emergence of the effective macroscopic equations in mathematically rigorous terms.

The exact derivation of effective equations is one of the central problems of non–equilibrium statistical mechanics. Though we are still very far from a complete realization of this programme, considerable progress has been made in the last years in developing new mathematical methods. In particular, several interesting questions regarding classical systems in the low density limit and quantum systems in the mean field and in the Gross–Pitaevskii regime are now approachable by rigorous mathematical analysis.

The main goal of this workshop was to connect researchers interested in the derivation and in the analysis of effective macroscopic equations. The workshop promoted the exchange of information concerning the techniques that have been developed in different contexts. Several results have been presented related to derivations of effective equations starting from microscopic quantum or classical models. Additionally, various results concerning the mathematical analysis of the limiting partial differential equations have been discussed. We included the Boltzmann equation, the Landau equation, the Vlasov equation, Hartree and Hartree–Fock equations, and the Gross–Pitaevskii equation. Special attention was given to the comparison of methods and tools from different fields.

Activities

During the five days of the workshop there were 16 talks of 50 minutes and 9 talks of 30 minutes given by young participants.

The slides of most seminars will remain available on the workshop webpage.

Herbert Spohn [TUM, Munich, Germany]

Equilibrium time correlations for anharmonic chains

Abstract: Anharmonic chains are one–dimensional mechanical systems with three conservation laws, stretch, momentum, and energy, the most–studied model systems being the Fermi–Pasta–Ulam chains. Of interest are the equilibrium time correlation of the conserved fields. We explain a nonlinear extension of fluctuating hydrodynamics. For a single component the equations reduce to the one–dimensional stochastic Burgers equation, alias Kardar–Parisi–Zhang equation. The corresponding stationary process has been studied mathematically in considerable detail. Anharmonic chains are a natural extension to three components. The analysis of nonlinear fluctuating hydrodynamics leads to the universal scaling form of the heat peak and sound peaks.

Giovanni Gallavotti [Sapienza U, Rome, Italy]

Equivalence of non–equilibrium ensembles and representation of friction in turbulent flows: the Lorenz '96 model

Abstract: We construct different equivalent non–equilibrium statistical ensembles in a N–degrees of freedom model of atmospheric turbulence, introduced by Lorenz in 1996. The vector field can be decomposed into an energy–conserving, time–reversible part, plus a non-time reversible part, including forcing and dissipation. We construct a modified version of the model where viscosity varies with time, in such a way that energy is conserved, and the resulting dynamics is fully time–reversible. The purpose is to test conjectures on a theory of ensembles in non equilibrium statistical mechanics and turbulence as well as the chaotic hypothesis and the fluctuation relation. This leads to the proposal that using a model of a fluid where viscosity is kept constant is just one option, and not necessarily the only option, for describing accurately its statistical and dynamical properties.

Amit Einav [Cambridge U, Cambridge, United Kingdom]

Subadditivity of the entropy on the sphere

Abstract: It is an interesting well known fact that the relative entropy of the marginals of a density with respect to the Gaussian measure on Euclidean space satisfies a simple subadditivity property. Surprisingly enough, when one tries to achieve a similar result on the N–sphere a different factor appears in one side of the inequality, causing a deviation from the simple 'equivalence of ensembles principle' in equilibrium Statistical Mechanics. In our talk we will present conditions under which one can get an almost subadditivity property; i.e. the constant factor in the entropic inequality on the sphere can be replaced with a factor that tends to 1 as the dimension of the sphere goes to infinity.

Maxime Hauray [Aix–Marseille U, Marseille, France]

A quantum jump process modelling decoherence induced by the environment

Abstract: I will first describe a one dimensional quantum model describing the interaction of a heavy particle with a light one. In the limit of small mass ratio, we obtain rigorously a simple "instantaneous" collision operator, acting on the density matrix of the heavy one. We study some of its properties and

use it to perform some fast numerical simulations, which show the apparition of decoherence on this toy model. This is a joint work with Riccardo Adami and Claudia Negulescu. Then I will describe a quantum jump process built upon that "instantaneous" collision operator, and show that when the number of interactions and the influence of each interaction are properly rescaled, solutions of the jump process converge towards solutions of a stochastic Lindblad or Master equation. This is a joint work with Christophe Gomez.

Sara Merino Aceituno [Cambridge U, Cambridge, United Kingdom]

Anomalous energy transport in FPU–beta chain

Abstract: FPU chains (an array of weights chained to their neighbors via springs) are used to model 1–dimensional crystals. Depending on the interaction potential considered, anomalous heat transport is expected. Based on the results of Lukkarinen and Spohn, we study the emergence of the fractional heat equation with laplacian of order 4/5 for FPU chains with quartic interaction potentials.

Mario Pulvirenti [Sapienza U, Rome, Italy]

Backward clusters, correlations and Wild sums for a hard sphere system in a low–density regime

Abstract: In this talk I discuss some recent results concerning the formation of backward clusters and the nature of the correlations for a hard–sphere system in a low–density regime.

Thierry Bodineau [École Polytechnique, Palaiseau, France]

The Brownian motion as the limit of a deterministic system of hard–spheres

Abstract: We consider a tagged particle in a diluted gas of hard spheres. Starting from the hamiltonian dynamics of particles in the Boltzmann–Grad limit, we will show that the tagged particle follows a Brownian motion after an appropriate rescaling. We use the linear Boltzmann equation as an intermediate level of description for one tagged particle in a gas close to global equilibrium. This is joint work with I. Gallagher and L. Saint–Raymond.

Giada Basile [Sapienza U, Rome, Italy]

Fick's law for the Lorentz model

Abstract: We consider the Lorentz model in a slab with two mass reservoirs at the boundaries. We show that, in a low density regime, there exists a unique stationary solution for the microscopic dynamics which converges to the stationary solution of the heat equation, namely to the linear profile of the density. In the same regime the macroscopic current in the stationary state is given by the Ficks law, with the diffusion coefficient determined by the Green–Kubo formula.

Laurent Desvillettes [ENS, Cachan, France]

About the structure of Landau's operator of collision

Abstract: We consider the Landau operator with Coulomb interaction. We show that its entropy dissipation behaves, up to a change of weight, like the entropy dissipation of the standard Fokker–Planck operator. As a consequence, we are able to get new estimates for the spatially homogeneous Landau equation in the Coulomb case.

François Golse [École Polytechnique, Palaiseau, France]

Kinetic theory in extended phase space

Abstract: We review recent results obtained in collaboration with E. Bernard and E. Caglioti on the homogenisation problem for the linear Boltzmann equation for a monokinetic population of particles set in a periodically perforated domain, assuming that particles are absorbed by the holes. We distinguish a critical scale for the hole radius in terms of the distance between neighbouring holes, derive the homogenised equation under this scaling assumption, and study the asymptotic mass loss rate in the long time limit. The homogenised equation so obtained is set on an extended phase space as it involves an extra time variable, which is the time since the last jump in the stochastic process driving the linear Boltzmann equation.

Mathieu Lewin [U Paris Dauphine, Paris, France]

Derivation of nonlinear Gibbs measures from many–body quantum mechanics

Abstract: Nonlinear Gibbs measures have recently become a useful tool to construct solutions to time–dependent nonlinear Schrödinger equations with rough initial data. In this talk I will explain how these measures can be obtained from the corresponding many–particle quantum Gibbs states, in a mean–field limit where the temperature T diverges and the interaction behaves as $1/T$. Our results cover the defocusing nonlinear Schrödinger case on the circle, as well as smoother interactions in higher dimensions. Joint work with P.T. Nam and N. Rougerie.

Peter Pickl [LMU, Munich, Germany]

Mean field limits for gases of large volume

Abstract: In recent years there has been a lot of progress in the understanding of quantum mechanical mean field limits. Usually one considers either the case of a gas of fixed volume and large volume while the coupling constant scales like the inverse density. Or one considers dilute gases. In this talk I will present new results where the mean field description holds for gases of high volume and high density. Both the Bosonic and the Fermionic case shall be presented and the physical relevance of the system discussed.

Marcello Porta [U Zürich, Zürich, Switzerland]

Mean–field evolution of fermionic systems

Abstract: In this talk I will discuss the dynamics of N interacting fermions in the mean–field regime. Compared to the bosonic case, fermionic mean–field scaling is naturally coupled with a semiclassical scaling, making the analysis more involved. I will consider initial data which are close to a Slater determinant, whose reduced one–particle density matrix ω_N is an orthogonal projection with an appropriate semiclassical structure. Under some regularity assumptions on the interaction potential I will show that the time evolution of such initial data stays close to a Slater determinant, with reduced one–particle density matrix given by the solution of the Hartree–Fock equation with initial data ω_N. The result holds for all (semiclassical) times, and gives effective bounds on the rate of convergence towards the Hartree–Fock dynamics as N goes to infinity. This is joint work with Niels Benedikter and Benjamin Schlein.

Jan Philip Solovej [U Copenhagen, Copenhagen, Denmark]

Bogoliubov theory at positive temperature

Abstract: I will discuss Bogoliubov theory in the translation invariant case of a Bose gas. The theory arises by restriction to translation invariant quasi–free states. I will introduce the positive temperature

pressure functional and the corresponding ground state energy functional. I will describe properties of the functional and to what extent it can be said to be a good approximation to the many–body quantum theory. This is joint work with Robin Reuvers and Marcin Napiorkowski.

Christian Hainzl [U Tübingen, Tübingen, Germany]

Many body quantum systems in the BCS approximation

Abstract: We consider the BCS description of a Fermi gas. In the strong coupling low density limit, the system at zero temperature is well approximated by the Gross-Pitaevskii functional, describing a Bose-Einstein condensate of fermion pairs. A similar result is true for translation-invariant quasi-free states where the BCS functional includes direct and exchange energies. Furthermore in the dilute limit, the time-evolution of the BCS state is well described by a time-dependent Gross–Pitaevskii equation. We show that, in the weak coupling case close to the critical temperature, the Ginzburg–Landau theory can be rigorously obtained from the BCS model.

Julien Sabin [U Paris–Sud, Orsay, France]

The Hartree equation for infinite quantum systems

Abstract: We consider a nonlinear Schrödinger equation of Hartree type describing the time evolution of infinitely many interacting quantum particles. The state of the system is not described by a wave function but rather by a bounded operator on the underlying Hilbert space. We prove the asymptotic stability of particular stationary solutions which are translation–invariant operators describing homogeneous Fermi gases. This relies on the use of new Strichartz inequalities for systems of orthonormal functions, a recent result due to Frank, Lewin, Lieb, and Seiringer, which capture the dispersive effects in infinite quantum systems. This is joint work with M. Lewin.

Paolo Antonelli [GSSI, L'Aquila, Italy]

On a class of nonlinear Schrödinger equations with nonlinear damping

Abstract: We consider equations of nonlinear Schrödinger type augmented by nonlinear damping terms. We show that nonlinear damping prevents finite time blow–up in several situations, which we describe. We also prove that the presence of a quadratic confinement in all spatial directions drives the solution of our model to zero for large time. In the case without external potential we prove that the solution may not go to zero for large time due to (non-trivial) scattering.

Jani Lukkarinen [U Helsinki, Helsinki, Finland]

Hydrodynamics without scaling limits: thermalization in harmonic particle chains with velocity flips

Abstract: Harmonic particle chains with velocity flips provide a simple one–dimensional toy model with normal heat conduction. We discuss how replication of dynamical degrees of freedom can be used to “exponentiate” part of the evolution without resorting to moment hierarchies. For the chain, this yields a closed evolution equation –similar to renewal equations– for the noise–averaged kinetic temperature profile. We prove that its solutions can be approximated by solutions to a certain discrete diffusion equation with errors that are $O(Lt^{-3/2})$ for chains of length L and at time t. The estimate is uniform in space, and holds for all large enough chains and any deterministic initial data. In particular, no scaling limits are necessary, and estimates for the accuracy of dynamic Fourier's law can be obtained for fixed finite chains.

Alexander Bobylev [Karlstad U, Karlstad, Sweden]

Boltzmann equation and hydrodynamics beyond the Navier–Stokes level

Abstract: We present a review of results on hydrodynamic equations at the Burnett level, derived from the Boltzmann equation. A well-known problem here is connected with regularization of classical ill-posed Burnett equations. Among the several ways to deal with this problem, one possible approach is based on infinitesimal changes of variables. This shows that the way of truncation of the Chapman-Enskog series is not unique. The natural replacement for classical Burnett equations is a two–parameters set of stable Generalized Burnett equations.

Kleber Carrapatoso [ENS, Cachan, France]

Kac's program for the Landau equation

Abstract: We prove a quantitative propagation of chaos and entropic chaos, uniformly in time, for the spatially homogeneous Landau equation in the case of Maxwellian molecules. We improve the previous results by Fontbona, Guérin and Méléard and the one by Fournier where the propagation of chaos is proved for finite time. Moreover, we prove a quantitative estimate on the rate of convergence to equilibrium uniformly in the number of particles.

Raffaele Esposito [M&MoCS U dell'Aquila, L'Aquila, Italy]

Stationary solutions to the Boltzmann equation and their hydrodynamic limit

Abstract: In a two– or three–dimensional domain of arbitrary shape I consider a rarefied gas described by the Boltzmann equation with diffuse reflection boundary conditions modelling the contact with thermal walls where a temperature profile is given. I describe recent results showing, for fixed Knudsen numbers, the existence, uniqueness, stability and positivity and regularity properties of the stationary solution under the assumption that the temperatures at the boundary are close to the homogeneous one. The asymptotic when the Knudsen number is small (hydrodynamic limit) requires a more accurate analysis. I review the few results based on special geometries and describe the difficulties for a general geometry.

Mahir Hadžić [King's College London, London, United Kingdom]

On the small redshift limit of steady states of the Einstein–Vlasov system and their stability

Abstract: Families of steady states of the spherically symmetric Einstein–Vlasov system are constructed, which are parametrized by the central redshift. It is shown that as the central redshift tends to zero, the states in such a family are well approximated by a steady state of the Vlasov–Poisson system, i.e., a Newtonian limit is established where the speed of light is kept constant and the limiting behavior is analyzed in terms of a parameter which is tied to the physical properties of the individual solutions. The crux of the argument is to use a suitable rescaling of relativistic solutions, which yields an effective ODE satisfied in the limit by the solutions of the Vlasov–Poisson system. This result is then used to investigate the stability properties of the relativistic steady states with small redshift parameter. This is joint work with Gerhard Rein.

Juan Velázquez [HCM, Bonn, Germany]

Singularity formation for kinetic equations with cubic nonlinearities

Abstract: In this talk I will discuss some recent results concerning the formation of singularities for two particular kinetic equations, namely Nordheim's equation for bosons and the Weak Turbulence kinetic equation associated to the Nonlinear Schrödinger equation. The solutions of these equations can yield singularity formation in finite time for spatially homogeneous particle distributions. The physical

significance of these singularities will be discussed. Seemingly, this singular behaviour is related to the formation of Bose–Einstein condensates. Issues like the long time asymptotics for the solutions of the Weak Turbulence equation will be also discussed.

Robert Seiringer [IST Austria, Klosterneuburg, Austria]

Validity of the Bogoliubov approximation for the excitation spectrum of weakly interacting bosons

Abstract: We investigate the low–energy excitation spectrum of a Bose gas confined in a trap, with weak long–range repulsive interactions. In particular, we prove that the spectrum can be described in terms of the eigenvalues of an effective one–particle operator, as predicted by the Bogoliubov approximation.

Phan Thành Nam [U Cergy–Pontoise, Cergy–Pontoise, France]

Bogoliubov correction to the Hartree dynamics of bosons

Abstract: We consider the dynamics of a large system of interacting bosons in the mean–field regime. We prove that the corrections to the Hartree dynamics of a Bose–Einstein condensate are described by an effective Hamiltonian derived from Bogoliubov approximation. We use a direct method in the N–particle space, which is different from the one based on coherent states in Fock space.

Specific information on the workshop

One of the objectives of this meeting was to bring together young researchers and encourage scientific discussions and collaborations between them and with leading experts in the topics of the workshop.

There were many master and PhD students as well as postdocs: Niels Benedikter, Chiara Boccato, Kleber Carrapatoso, Serena Cenatiempo, Esther Daus, Helge Dietert, Amit Einav, Giuseppe Genovese, Mikaela Iacobelli, Maximilian Jeblick, Dustin Lazarovici, Nikolai Leopold, Matteo Marcozzi, Dawan Mustafa, Sara Merino Aceituno, Phan Thanh Nam, Alessia Nota, Sören Petrat, Marcello Porta, Julien Sabin, Chiara Saffirio, Anton Samojlow, Sergio Simonella, Hanne Van der Bosch, Raphael Winter.

Some of the young participants presented their research in the 30 minutes talks (see list above).

Invited scientists:

Paolo Antonelli, Anton Arnold, Giada Basile, Niels Benedikter, Michael Bishop, Alexander V. Bobylev, Chiara Boccato, Thierry Bodineau, Kleber Carrapatoso, Serena Cenatiempo, Michele Correggi, Esther Daus, Laurent Desvillettes, Helge Dietert, Andrey Dymov, Amit Einav, Raffaele Esposito, Giovanni Gallavotti, Miguel Angel Garrido Garcia, Giuseppe Genovese, Francois Golse, Alex Gottlieb, Ennio Gozzi, Mahir Hadzic, Christan Hainzl, Maxime Hauray, Mikaela Iacobelli, Maximilian Jeblick, Jonas Lampart, Dustin Lazarovici, Nikolai Leopold, Mathieu Lewin, Juan José Lopez Velazquez, Jani Lukkarinen, Matteo Marcozzi, Simon Mayer, Rossana Marra, Sara Merino Aceituno, David Mitrouskas, Thomas Moser, Dawan Mustafa, Phan Thanh Nam, Alessia Nota, Ashraf Owis, Boris Pawilowski, Soeren Petrat, Peter Pickl, Marcello Porta, Harald Posch, Mario Pulvirenti, Robin Reuvers, Nicolas Rougerie, Julien Sabin, Chiara Saffirio, Anton Samojlow, Benjamin Schlein, Robert Seiringer, Sergio Simonella, Jan Philip Solovej, Thomas Oestergaard Soerensen, Herbert Spohn, Hanne Van den Bosch, Johannes von Keler, Raphael Winter, Jakob Yngvason.

Research in Teams

Louis Funar and Athanase Papadopoulos: Mapping Class Group Dynamics and Simplicial Complexes on Surfaces of Infinite Type

Collaborators: Louis Funar (Institut Fourier, U Grenoble), Athanase Papadopoulos (U of Strasbourg, and CNRS)

Dates: January 6 – Februar 3, 2014

Budget: ESI € 4 480.

Scientific background

Both researchers, along with several collaborators and some of their PhD students, were involved in the study of automorphisms of various complexes of topological origin, which are built using the combinatorial structures behind the set of homotopy classes of curves on the surface. The typical result is that the group of automorphisms of such a complex is precisely the outer automorphism group of the fundamental group of the surface, namely the (extended) mapping class group. Such a phenomenon is called rigidity.

This type of result was pioneered by N. Ivanov, as a combinatorial analogue of Royden's theorem concerning the biholomorphism group of the Teichmüller space. Recently, this point of view became one of the main road for attacking questions on the structure of the mapping class group. Furthermore, Masur and Minsky proved that the curve complex is hyperbolic in the sense of Gromov, which initiated intense work on the geometry of that group.

Project aims and scope

Our project concerned Teichmüller spaces and their generalizations and mapping class groups of surfaces of not necessarily finite topological type, that is, surfaces whose fundamental group might not be finitely generated. The surface may have infinite genus, or an infinite number of boundary components or of cusps.

There were two parts of the research project.

1. The study of the geometric properties of simplicial complexes associated to surfaces of possibly infinite type and mapping class group action on these complexes. The complexes include the curve complex, the pants decomposition complex and the ideal triangulation complex.

2. The dynamics of the action of the mapping class group of surfaces on various representation spaces and the relation with the Thompson groups in the case of infinite type surfaces.

The project started at the special trimester on Teichmüller theory, at ESI, February to April 2013. Because of the wealth of activities during that period and because of several duties we have, we decided to apply for a Research-in-pair period at ESI and come back to work especially on that project.

In the case of surfaces of infinite type a new phenomenon arises: although pants complexes seem to be rigid, the curve complexes are more flexible. This should be correlated to a similar phenomenon in the case of the profinite groups of surfaces and their outer automorphisms groups, leading on one side to rigid profinite complexes and on the other side to the various versions of the Grothendieck-Teichmüller group as a subgroup of the Galois group of $\overline{\mathbb{Q}}$ over $\mathbb{Q}$. We are in the process of exploring this fact, in particular for infinite surfaces (inductive limit) or else for solenoids (projective limits) and show that the analogue of the Grothendieck-Teichmuller group has an explicit and meaningful description in this setting. This is related also to a conjecture of Penner and Saric about the finite presentation of the automorphisms group of the solenoid.

A second direction concerned earlier work of A. Papadopoulous on topological dynamics of the action of subgroups of mapping class groups on projective measured laminations, which is closely related to L. Funar's recent work on the Johnson subgroup of the mapping class groups of character varieties (associated to compact Lie groups) concerning measurable dynamics, namely ergodicity questions. The question of ergodicity for arbitrary subgroups of mapping class groups seems rather difficult, as the main ingredients are of geometric nature: Goldman used integrable systems description and L. Funar and J. Marché used Taylor expansions of trace functions around the trivial representation to obtain infinitesimal transitivity and bootstraps arguments on normal subgroups. These methods do not seem to work neither for the non-orientable surfaces (where the ergodicity of the full group is known to hold by results of F.Palesi) nor for other smaller subgroups. One main conjecture is that the subgroup generated by two Dehn twists along filling curves acts ergodically. The question for a single pseudo-Anosov seems already rather difficult. The minimal decomposition of the action is also not clear and one can only believe that orbits are either finite or dense. Recent work in this area concerns the ergodic decomposition of the action on measured laminations by Lindenstrauss and Mirzakhani. The case where the Lie group is just a torus is already very interesting and completely nontrivial: the stiffness of the action of some subgroup of $SL(n,\mathbb{Z})$ on a torus and the classification of probabilities invariant by a non-elementary subgroup was only found recently by Bourgain, Furman, Lindenstrauss and Mozes and the general case of homogeneous spaces by Benoist and Quint in a series of remarkable papers. The general case of a character variety associated to a non-abelian group seems to need additional techniques and methods mixing both geometrical and ergodic arguments.

Outcomes and achievements

Concerning combinatorial actions of mapping class groups of surfaces of infinite type we worked on the geometry of the solenoid. This is a fiber space over a closed Riemann surface of genus ≥ 2 obtained through the construction of a tower of coverings. It was introduced by Sullivan in the early 1990s as the inverse limit of a tower of finite-sheeted pointed coverings of a fixed closed surface of hyperbolic type. More precisely, we study the so-called "punctured solenoid", introduced by D. Saric, where the coverings are allowed to have some ramification at some distinguished points. This theory is adapted to Penner's decorated Teichmüller theory. The aim of our work was to show that mapping class groups of the solenoid are naturally identified with the automorphism group of some simplicial complexes associated with this object. We make relations with Grothendieck's theory of the Teichmüller tower.

This theory aims at extending a recent result obtained by L. Funar and M. Nguyen in [FM], in a work which was completed after the first ESI visit in 2013 and acknowledges ESI support. The cited paper deals with the case when we have an infinite type genus zero surface and its pants decompositions complex. The pants complexes of large compact surfaces are rigid. This is also true for an infinite ribbon tree when the corresponding automorphism group of the complex of decompositions is the Thompson group T, as it was proved by A. Fossas and M. Nguyen. In contrast, the pants decomposition complex of a sphere punctured along a Cantor subset is not rigid and the automorphism group of the complex is a topological group, namely the mapping class group of those homeomorphisms of the surface stabilizing a pants decomposition at infinity. This amounts to add to the universal mapping class group $\mathcal{B}$ in genus zero, which is the expected automorphism group, those infinite products of Dehn twists along disjoint curves in the pants decomposition which converge to infinity. This is a first step in understanding the solenoid case: in the infinite type surface case the various complexes naturally embed one into the other, according to how subsurfaces lie in larger surfaces. In the solenoid case the surfaces are related by coverings (and not by embeddings) and we need to connect the various complexes associated to these finite type surfaces in a less canonical way, either by adding extra cells or else using the projection maps defined by Schleimer.

L. Funar also worked on a joint project with Y. Neretin concerning the $\mathcal{C}^1$-diffeomorphisms of Cantor sets. Specifically, we considered a tame Cantor subset of a compact manifold M, satisfying a suitable sparsity condition. Our main concern was the group of classes of diffeomorphisms preserving the Cantor set, up to the equivalence relation which identifies those diffeomorphisms having the same action on the Cantor. One of the main results states that this group is countable. Another result states that the corresponding $\mathcal{C}^2$-mapping class group is countable. When we considered the ternary central Cantor set (with arbitrary parameters) we proved that the first group is one of the three Thompson groups F,T or V (the last two being the first examples of simple finitely presented infinite groups), while the second group is a braided Thompson group, whose various fersions were previously studied by M. Brin, P. Dehornoy, L. Funar and C. Apoudjian. This might lead to a new construction of infinite simple groups as automorphisms groups of fractals in various categories, like smooth, Hölder, bi-Lipschitz or quasi-symmetric. There is already a preliminary version of a manuscript containing these results, but the project has many ramifications which will be explored in the next future.

Another subject on which progress was made was the understanding of a mapping class group representation of the Torelli group earlier constructed by Gunning and Chueshev. These come from the action of the Torelli group on the character variety of $GL_1(C)$-representations of a surface group $\pi_1\Sigma_g$. Specifically if ρ is the class of a representation, since its image is abelian there is a Torelli action on the twisted cohomology group $H^1(\pi_1\Sigma_g, V_\rho) \cong C^{2g-2}$, where V_ρ is the twisted local system determined by ρ. Using recent results by Grunewald, Larsen, Lubotzky and Malestein we showed that the image of the Torelli group is a finite index subgroup in $Sp(2g-2, Z[q])$, at points q corresponding to cyclotomic characters.

A. Papadopoulos worked also on two papers, with Norbert A'Campo and Lizhen Ji, whose aim is to put in a modern perspective some works of Grothendieck on Teichmüller theory and moduli spaces and to make it accessible to topologists and geometers. The first paper is titled "On Grothendieck's construction of Teichmüller space". It concerns the Teichmüller curve as a space representing a functor from the category of fiber spaces over analytic spaces whose fibers are Riemann surfaces or algebraic curves into the category of sets. The second paper is entitled "Grothendieck-Teichmüller theory" and it concerns the absolute Galois group $\Gamma_{\mathbb{Q}}$ of $\mathbb{Q}$, that is, the automorphism group of the tower of finite extensions of $\mathbb{Q}$, in relation with the Teichmüller tower, dessins d'enfants, and other related objects and Grothendieck's conjecture that some natural homomorphisms between the absolute Galois group and outer automorphism groups of algebraic fundamental groups of profinite objects are isomorphisms. The two papers will appear in the "Handbook of Teichmüller theory" EMS Publishing House, volume V.

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[FM] Louis Funar, Maxime Nguyen, On the automorphisms group of the asymptotic pants complex of an infinite surface of genus zero, arXiv:1308.6143.

[GLLM] Fritz Grunewald, Michael Larsen, Alexander Lubotzky, Justin Malestein, Arithmetic quotients of the mapping class group, arXiv:1307.2593.

Preprints contributed:

L.Funar, *The topology of closed manifolds with quasi-constant sectional curvature*, `arXiv:1406.0327`, RIT.

L.Funar, Yury Neretin, *Diffeomorphisms groups of Cantor sets and Thompson-type groups*, `arXiv:1411.4855`, RIT.

Fritz Gesztesy et al: Scattering Theory and Non-commutative Analysis

Collaborators: Alan Carey (ANU, Canberra), Fritz Gesztesy (U of Missouri), Harald Grosse (U of Vienna), Denis Potapov, and Fedor Sukochev (UNSW, Sydney).

Visitor: Galina Levitina, a student from the University of NSW, Sydney, Australia, also attended as she was visiting the Mathematics Department of the University of Vienna for two weeks during the RiT period.

Dates: June 22 – July 22, 2014

Budget: ESI € 9 200.

Scientific background

The part of scattering theory that was relevant to this proposal is the spectral shift function theory of Krein, Koplienko, and Potapov–Skripka–Sukochev [GM, GPS, PSS, P].

The objective was to understand these spectral functions for scattering for supersymmetric quantum Hamiltonians and Dirac type operators on non-compact manifolds. In particular, our aim was to connect the spectral properties of the operators under investigation to invariants such as spectral flow, the Fredholm index, and generalisations. In this sense the proposal was partly about spectral geometry.

An initial step was taken in [ACDS] who showed that, when both exist, spectral flow is given by Krein's spectral shift function. This work was generalised in [GLMST] in 2011, in a long paper in Advances in Math. Spectral flow relates directly to the topology of the underlying manifold on which the path of operators is defined. The aim was to consider how the spectral shift function generalises spectral flow to non-Fredholm situations. We also add that in unpublished work, Carey and Kaad have introduced a new spectral invariant (the 'homological index') that we expect to be expressible in terms of the spectral shift function.

Work to date has been in terms of self adjoint operators D and perturbations A such that for complex λ not in the spectrum of D the product $A(\lambda - D)^{-1}$ is trace class (i.e., one employs a relatively trace class condition). The relatively Schatten class condition such as $A(\lambda - D)^{-n}$, $n = 2,3,\dots$, is trace class is what would be expected for higher-dimensional manifolds.

Primary objective: Our principal aim was to relax this (severe) relatively trace class perturbation restriction and to study examples in one, two and three dimensions in order to provide insight into general theory and applications.

Outcomes and achievements

The four weeks in ESI were spent primarily on investigating simple models. Even for one dimensional examples of differential operators the relatively trace class perturbation assumption, mentioned above, is not satisfied.

However, we were successful in the end of providing a complete theory for the case of one dimension. Here we considered perturbations of the differential operator $-i(d/dt)$ on $L^2(\mathbb{R})$ by matrix-valued potentials. We found that the substitute for the relatively trace class perturbation assumption is to allow relatively Hilbert–Schmidt perturbations. By using an approximation technique exploiting pseudodifferential operators we were able to prove analogues of the main results of [GLMST] and in some cases strengthen them.

Most importantly we proved the existence of a class of examples of pseudo-differential operators in any dimension to which the method of [GLMST] applies. These examples form the basis of an attack on higher dimensional cases.

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[GM] F. Gesztesy and K.A. Makarov, *The Ξ operator and its relation to Krein's spectral shift function,* J. Anal. Math. **81** (2000), 139–183.

[GPS] F. Gesztesy, A. Pushnitski, and B. Simon, *On the Koplienko spectral shift function. I. Basics*, J. Math. Phys., Anal., Geometry, **4** (2008), 63–107.

[PSS] D. Potapov, A. Skripka, F. Sukochev, *Spectral shift function of higher-order*, Invent. Math. **193**, 501–538 (2013).

[P] A. Pushnitski, *The spectral flow, the Fredholm index, and the spectral shift function*, in *Spectral Theory of Differential Operators: M. Sh. Birman 80th Anniversary Collection*, T. Suslina and D. Yafaev (eds.), AMS Translations, Ser. 2, Advances in the Mathematical Sciences, Vol. 225, Amer. Math. Soc., Providence, RI, 2008, pp. 141–155.

Publications:

There are three articles which describe our results thus far:

A. Carey, F. Gesztesy, G. Levitina, D. Potapov, F. Sukochev, and D. Zanin, *On index theory for non-Fredholm operators: a $(1+1)$-dimensional example*, 2014, submitted.

A. Carey, F. Gesztesy, G. Levitina, and F. Sukochev, *A framework for index theory applicable to non-Fredholm operators*, 2014, submitted.

A. Carey, F. Gesztesy, G. Levitina, D. Potapov, F. Sukochev, and D. Zanin, *Trace formulas for a* $(1+1)$*-dimensional model operator*, 2014, submitted.

Herbert Muthsam et al: Multi-scale Models of Magnetohydrodynamic (MHD) Turbulence in Solar Convection

Collaborators: Friedrich Kupka and Herbert Muthsam (U of Vienna), Arakel Petrosyan (Russian Academy of Sciences), and Oleh Pomazan (National Research Nuclear University MEPhI)

Dates: September 2014

Budget: ESI € 4 800.

Scientific background

Turbulence represents one of the most important phenomena, both in astrophysical and in laboratory plasmas. There is increasing evidence of the key role played by turbulence within different physical processes taking place in magnetofluids, like transport phenomena or the nonlinear dynamics of such complex systems. The presence of velocity and magnetic field fluctuations in a wide range of spatial and time scales has been directly detected in the solar interior with helioseismology (e.g. [HUGH12]).

Complete information about turbulent fluid flow could be obtained by means of a direct numerical simulation (DNS) which refers to the numerical solution of the complete, nonstationary system of magnetohydrodynamic equations. This approach would allow resolving all scales of charged fluid flows and does not require additional hypotheses (often: closure relations) beyond the MHD equations themselves. However, direct numerical computation of MHD turbulence faces fundamental difficulties in case of the Sun because of the large hydrodynamic and magnetic Reynolds numbers typical for the processes studied: the number of degrees of freedom for the turbulent flow is enormous and consequently the number of required mesh points is utterly beyond any conceivable direct numerical simulation. Therefore, new computational methods need to be developed to tackle solar convection flows with high Reynolds number. These typically consist of subgrid modelling. For a review on subgrid modelling for MHD consult [CHER14].

Project aims and scope

We planned to advance mathematical tools to understand solar convection using the package ANTARES (A Numerical Tool for Astrophysical RESearch; see [MUTH10], [MUN13])

which has been developed at the Institute of Mathematics at the University of Vienna for simulations of solar granulation and other astrophysical flows.

To achieve this we proposed to critically review the state of the art and recent developments in applications of Large Eddy Simulations (LES) for studies of various problems of MHD flows in general and in solar convection in particular, to validate LES for MHD turbulent flow modeling in solar convection and to develop theoretically solid subgrid-scale models being relevant for statistical properties of MHD turbulence at different heliocentric distances of the solar flows.

LES is a multi-scale computational modeling approach in which the large-scale part of the turbulent flow is computed directly, while the small-scale one is modeled. The possibility of using filtering operations in LES for a decomposition of turbulent flow characteristics into large-scale and small-scale parts originates from sufficient isotropy, homogeneity and universality of the small scales of turbulent flow. The filtering of LES induces a closure problem in which the dynamic effects of the small-scale turbulence on the primary flow-features need to be represented by introducing subgrid scale models for both the turbulent stresses and magnetic source terms. MHD problems differ from those of the neutral fluid dynamics. MHD equations contain two vector fields, which introduces considerably more freedom into the dynamics. Also, there are self-organization processes in MHD turbulence that have no hydrodynamic counterpart. Conservation of cross-helicity leads namely to highly correlated, or aligned, states, and conservation of magnetic helicity gives rise to the formation of force-free magnetic configurations. New applications of LES raise old questions concerning the use of subgrid-scale (SGS) models: there is no guarantee that the results obtained for hydrodynamics of a neutral fluid can be directly extended to the case of MHD as a consequence of the above-mentioned distinctions.

Achievements and ongoing work

During one month of joint work in September 2014 we concentrated on test computations with the ANTARES code for which the Smagorinsky parametrization of turbulent viscosity has already been implemented, and on the development and implementation of a subgrid-scale model for LES involving also the magnetic induction equation, based on ideas similar to the Smagorinsky model.

Concerning the issue of filtering, we came to the conclusion that we should use implicit filtering as opposed to explicit filtering, where would have to apply a filtering operator before invoking the subgrid scale part. The explicit approach is justified by the fact that ANTARES uses a high-resolution computational core for the hyperbolic part of the equations which models also the short wavelengths relatively faithfully. In practice, it significantly simplifies the implementation and the numerical simulation of the complex flows. This is especially important in computational astrophysics where external forces play a significant role: for example, radiative forcing does not have a universal part which is conveniently filtered. In the implicit approach, the filtering operator is contained in the basic discretization, and in this case the filtering scales are smaller than the grid spacing. Filtered MHD equations comprise unknown tensors, whereas in our approach we consider the initial equations as finite scale equations and extend them by adding the terms describing subgrid-scale stress tensors.

A Smagorinsky type parametrization was suggested for stresses in magnetic induction equations (see [CHER14]). Closer examination revealed that this parametrization may be implemented in ANTARES code unexpectedly simply by just adding turbulent magnetic diffusivity to otherwise preexisting code. This parametrization has been implemented during the first stay. Currently, test computations are performed which will be continuously discussed, in particular also during the second period of our Research in Teams.

Our future plans include studies of homogeneous turbulent spectra in presence of compressible convection, analyzing intermittent and non-trivial topological phenomena. In this next stage of our team project we plan to finish and submit papers reporting results of our investigations. We will continue to work on mathematical aspects assessing proper algorithms for dealing with subgrid scale motions according to the third task suggested in our proposal.

ENO (essentially non-oscillatory) and WENO (weighted ENO) methods can be realized as either finite difference or finite volume methods. In any case the (outer) derivative operator is discretized as a difference of fluxes through opposing boundaries of a grid cell divided by the distance of the two boundaries from each other. The higher spatial order is achieved by proper interpolation for this scenario. In the finite difference case, the grid values of a discretized expression are interpreted as function values assigned to the centre of each grid cell. In the finite volume case, the grid values represent volume averages over each grid cell. The two different methods are obtained by proper operators applied in each stage of the flux interpolation process occuring prior to numerical differentiation.

In either case the interpolation process leads to numerical dissipation and thus, from the viewpoint of hydrodynamics, to numerical viscosity. We intend to compare the numerical viscosity obtained for both the finite difference and finite volume version of the WENO scheme with the viscosity introduced by the chosen subgrid scale parametrizations in a qualitative and quantitative manner. This should allow a quantitative estimate of the gain of MHD simulations with subgrid scale parametrizations as opposed to MHD simulations which rely only on numerical viscosity to stabilize the computation. This is what we intend to accomplish in addition to the above-mentioned items (spectra of turbulence, analyzing topological phenomena and submitting papers).

We consequently suggested to continue the Research in Teams in the second 1 month's period for two external researchers (Petrosyan, Pomazan) in summer of 2015.

References

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Senior Research Fellows Programme

To stimulate the interaction with the local scientific community the ESI offers regular lecture courses on an advanced graduate level. These courses are taught by Senior Research Fellows of the ESI whose stays in Vienna are financed in a specific programme. In exceptional cases this programme also includes long-term research stays of small groups or individual distinguished researchers. These lecture courses are highly appreciated by Vienna's students and researchers.

This year's programme was focused on the following Lecture Courses:

Ludwik Dąbrowski (SISSA), Winter 2013/14:
Spinors: Classical and Quantum. Elements of Noncommutative Riemannian Geometry
Lectures and Exercise Classes (260155 VO): October 1, 2013 – January 31, 2014
Friday 10:30 – 12:00 (lecture) and 12:00 – 12:45 (tutorial)

Jan Philip Solovej (U Copenhagen), Summer 2014:
Many-body Quantum Physics
Lectures and Exercise Classes (260172 VO): March 5 – May 31, 2014
Tuesday 16:15 – 18:15 and Thursday 13:00 – 14:00

Visitors associated with Senior Research Fellowships:

Jens Kaad (SISSA), January 20 – January 26, 2014
Pierre Martinetti (U Napoli), January 23 – January 30, 2014
Andrzej Sitarz (Jagiellonian University), January 23 – January 30, 2014
Robin Reuvers (U Copenhagen), March 1 – May 31, 2014
Marcin Napiórkowski (U Warsaw), March 3 – April 30, 2014 and May 18 – 24, 2014
Mathias Makedonski (U Copenhagen), May 11 – 23, 2014
Natalie Gilka (U Melbourne), May 25 – 27, 2014

Ludwik Dąbrowski: Spinors: Classical and Quantum. Elements of Noncommutative Riemannian Geometry

Course

In the first part of my lecture course starting from basic notions of multilinear algebra and differential geometry, the Dirac operator on a Riemannian spin manifold M was introduced. Its basic properties were described and then the concept of a spectral triple was formulated. The distinction between spin and spin$_c$ structure was related to the charge conjugation (or the real structure).

The second part was devoted to the description of a number of additional properties of this canonical spectral triple, which permit to reconstruct fully the underlying geometry. In particular, it has been shown how to reconstruct the metric and the spin structure, and how to select among the Dirac-type operators the original Dirac operator by minimizing the Einstein-Hilbert action functional. In parallel the concept of the spectral triple and the additional properties as formulated by A. Connes in a fully noncommutative way were presented, so that certain noncommutative algebras can be used in place of the algebra of smooth functions on M. For that purpose some previous "layers" of noncommutative geometry were described briefly, that regard the (differential) topology and calculus, like the equivalence between (locally compact) topological spaces and C*-algebras, and between vector bundles and finite projective modules, projectors and K theory, the Hochschild cohomology, noncommutative integral, and others.

In the last part of the course three important noncommutative examples were presented and discussed: the noncommutative torus, the almost commutative spectral triple which uncovers the hidden noncommutative geometry behind the Standard Model of elementary particles, and equivariant spectral triples on the quantum two-sphere with the quantum group symmetry $SU_q(2)$.

Due to the necessary selection among the wealth of available material some well established topics (e.g. the index theory) were only briefly mentioned, as well as just few indispensable facts from the theory of the (elliptic) Laplace operator. Such a choice hopefully permitted to arrive fast to an active and interesting field of current research.

The only prerequisites for the course were the usual notions of multilinear algebra, differential geometry and Hilbert space operators.The presentation style was oriented towards the mathematical physicists, as the majority of the students and postdocs were from the Department of Physics and few from the Department of Mathematics.

I am planning to write up the presented material as lecture notes, hopefully in not too long period.

Research

During my stay at the ESI I managed to interact with the researchers from the U Vienna, among them I should certainly mention Prof. Harald Grosse with whom we worked on a common research project.

I would also like to mention that during the third week of January 2014 I took the opportunity to hear several seminars of the workshop “Time-frequency Analysis” at the ESI, which certainly will be helpful to reveal various possible links with noncommutative geometry.

Moreover, I am very grateful to the ESI for the invitation of three researchers Jens Kaad (SISSA, Trieste), Pierre Martinetti (Naples) and Andrzej Sitarz (Krakow), each for one week of collaboration. With them I have started three interesting projects which I am confident will lead soon to new manuscripts and then publications.

The stay at the ESI was very stimulating and enabled me to advance several of my projects considerably. I would like to thank the ESI Director for this extraordinary opportunity and the staff of the ESI for creating so favorable working conditions.

Preprints contributed:

Ludwik Dabrowski, Giovanni Landi, Franz Luef, *Sigma-model solitons on noncommutative spaces*, arXiv:1501.02331.

Jan Philip Solovej: Many-body Quantum Physics

Course

The course ran with a double lecture each week and a one hour exercise class. The course covered the notes on *Many-body Quantum Mechanics* by J.P. Solovej and most of the exercises in the notes. Additional material on the Lieb-Thirring inequality and the min-max Theorem was supplied to the students.

The course covered

- Tensor products and the formulation of many-body quantum mechanics
- The Lieb-Thirring inequality
- The min-max principle,
- Identical particles and statistics
- Fock spaces and second quantization
- Bogolubov transformations and Quasi-free states for fermions and bosons
- Quadratic Hamiltonians and their diagonalization
- The Bogolubov variational principle
- The Bogolubov approximation for bosonic systems

Between 10 and 15 students attended the lectures every week, a little less participated in the exercise classes but the participants here were very active. Several problems in the notes were open ended and led to the discussion of open problems, in particular, regarding criteria for diagonalizations of quadratic Hamiltonians.

Most students did not need credit for the course, but one student did and handed in exercises and passed the course.

Research

Most of the research during the stay was conducted in collaboration with the two visiting Ph.d. students Robin Reuvers and Marcin Napiórkowski. The research was closely connected to the lecture course as it focused on the Bogolubov variational model for interacting Bose gases in the thermodynamic limit. We defined and analyzed this model in great detail and have also used it to investigate the dilute limit of Bose gases. Our findings give new insight into Bose gases and their condensation. A manuscript is almost finished and should be ready for submittal in early 2015 either as one or two publications.

During the stay another project on entanglement entropy was initiated with Prof. Robert Seiringer from IST Austria. We have made significant progress on this project, but it is still ongoing and is expected to lead to a manuscript within a few months.

Finally, research is ongoing with Dr. P.T. Nam from IST Austria in settling certain issues of relevance to the lecture notes. These are issues regarding bosonic Bogolubov transformations which have never before been addressed in the literature.

Lecture Notes:

The lecture notes are still only in a draft version as some issues, as mentioned above, are still to be finally settled.

Simons Junior Professor Nils Carqueville

In 2013, following a suggestion of the hiring committee, the Rektor of the University of Vienna offered the Simons Junior Professorship at the ESI to Nils Carqueville (then at the Simons Center for Geometry and Physics, Stony Brook University). He accepted the call. Formally a member of the Faculty of Mathematics at Vienna University, he resumed his position at the ESI on March 1, 2014.

Teaching

Nils Carqueville taught the following courses/seminars within the general course programme of the University of Vienna.

Summer Term 2014:
Introduction to topological quantum field theory

Lecture Course, 2h, 250121 VO: March 4 – June 30, 2014 Tuesday 11:00 - 13:00

Course description: The functorial approach to topological quantum field theory goes back to Atiyah and Segal. After a motivational discussion of the Feynman path integral and a brief, self-contained introduction to monoidal categories, the lecture is roughly divided into three parts. (1) We will first study general properties of "closed d-dimensional TQFTs", and work out specific details for $d = 1,2,3$. Interesting examples in the two-dimensional case are topological Yang-Mills theory, sigma models and Landau-Ginzburg models. (2) We then move to "open/closed 2d TQFT" a la Moore-Segal and Lazaroiu, which "live" on surfaces that may have non-trivial boundary conditions. We will see that such TQFTs are equivalently described by an interplay of commutative Frobenius algebras and Calabi-Yau categories. (3) Finally we add further structure to the surfaces by embedding certain one-dimensional submanifolds. This leads to "2d TQFT with defects". A minimal generators-and-relations description analogous to (1) and (2) is not known in this case, but we will explain that 2-categories are the natural language here.

Topological quantum field theory
Seminar, 2h, 250122 SE: March 4 – June 30, 2014 Tuesday 14:00 - 16:00

Course description: This seminar is meant to accompany the lecture course VO 250121. One purpose is to study various examples in more detail. In the case of 2d TQFTs this may include (more on) supersymmetric sigma models, Landau-Ginzburg models, derived categories, Fukaya categories, matrix factorisations, and homological mirror symmetry. In the 3d case possible topics are Chern-Simons theory, Turaev-Viro models and Levin-Wen models. Another direction are "higher structures", either in the form of extended TQFTs and the cobordism hypothesis, and/or L_∞- and A_∞-algebras describing topological string theory. The focus of the seminar will be decided based on the participants' preferences.

Winter Term 2014/15:
Introduction to conformal field theory

Lecture Course, 2h, 250091 VO: October 2, 2014 – January 31, 2015 Thursday 11:15 - 12:45

Course description: This course is on two-dimensional conformal field theory (CFT), mostly from an axiomatic and algebraic point of view. After a short motivational discussion of axiomatic quantum field theory, we first study the group of conformal transformations and the associated Lie algebra in d-dimensional Euclidean space. The case $d = 2$ is special and we will see how the infinite-dimensional Virasoro algebra arises. We then define a CFT axiomatically by imposing certain constraints on correlation functions. To construct CFTs we are lead to introduce the notion of conformal vertex operator algebras and their representations. In this setting we prove existence and uniqueness theorems, and study conformal Ward identities and conformal blocks. The latter will allow us to make the connection with three-dimensional topological quantum field theory. Ultimately we aim to describe full CFTs on arbitrary Riemann surfaces in terms of tensor categories and Frobenius algebras, as developed in the work of Fuchs-Runkel-Schweigert; this may only be achieved during the summer term 2015.

The main prerequisite for the course is an interest in algebraic structures. An interest in quantum field theory and a rudimentary familiarity with differential geometry and basic category theory is useful, but not very essential. Both pure mathematicians and theoretical physicists are welcome.

Infinite-dimensional Lie algebras
Seminar Course, 2h, 250088 SE: October 2, 2014 – January 31, 2015 Thursday 14:00 - 15:45

Course description: The purpose of the seminar is to introduce and study certain infinite-dimensional Lie algebras (as well as aspects of their representation theory) which are relevant in conformal field theory, string theory, and for knot invariants. The first few sessions will review/introduce notions and results from the theory of finite-dimensional semi-simple complex Lie algebras. Then we move on to the Virasoro algebra Vir and its minimal representations; supersymmetric extensions of Vir; affine Kac-Moody algebras; Sugawara construction of Vir-representations. Further topics may include quantum groups and the basics of their 2-representation theory.

Simons Lecture Series on Mathematical Physics

Part of the use Carqueville has made of the start-up funds that came with the Simons Junior Professorship was to initiate a regular series of week-long lecture course of two hours per day. The idea was to invite two or three scientists to ESI every term to lecture on a field of their expertise, aimed at an audience of advanced master students, doctoral candidates, postdocs and interested faculty members. The first two such programmes were conducted in September and October 2014:

Magnus Engenhorst (U Bonn): **Bridgeland stability and BPS states**

Abstract: Stability conditions play a prominent role in algebraic geometry and string theory. The initial motivation comes from Michael Douglas' work on D-branes. Bridgeland stability has now a lot of applications, e.g. in birational geometry or Teichmüller theory. In this short course we see how one is naturally lead from the study of BPS states in supersymmetric field theories to stability conditions on certain (triangulated) categories associated with quivers with potential. We introduce the theory of (Bridgeland) stability conditions on triangulated categories and develop tools like tilting theory and t-structures. Further we discuss the relationship to Donaldson-Thomas invariants and (the categorification of) cluster algebras.

Alessandro Valentino (MPI Bonn): **Topological Quantum Field Theory via Higher Category Theory**

Abstract: In this series of lectures I will give an introduction to Topological Quantum Field Theories (TQFTs) as first formalized by Atiyah and Segal, namely as functors from a geometric category of cobordism to some suitable symmetric monoidal categories. More specifically, I will introduce elements of ∞-category theory which will allow to discuss in unified way extended theories, and in particular fully extended TQFTs. The cobordism hypothesis, which allows to completely classify fully extended theories, will be discussed as well. I will also discuss TQFTs with boundary conditions, and the relevance of the theory of module categories for 2-tier extended TQFTs on manifolds with boundaries. Finally, I will present some applications to Chern-Simons theories and Dijkgraaf-Witten theory.

Research

There are four main research projects Carqueville has been engaged with since his move to Vienna in March 2014.

The first focus was to finish his third joint paper with Ilka Brunner and Daniel Plencner, *Discrete torsion defects*. In it they continue their study of generalised orbifolds and apply it to the phenomenon of "discrete torision" when orbifolding by a finite group. In the case of Landau-Ginzburg models they explain how their approach recovers all known results in the bulk sector. They further introduce the notion of c-projective matrix factorisations (with c a second group cohomology class with values in $U(1)$) and explain how they describe the boundary and defect sectors. More generally, they prove that for any pivotal bicategory, any two objects of its orbifold completion that have the same base are orbifold equivalent. Equivalently, from any orbifold theory (including those based on nonabelian groups) the original unorbifolded theory can be obtained by orbifolding via the "quantum symmetry defect".

One of Carqueville's long-term aims is to develop the notion of "orbifold completion", which Ingo Runkel and he introduced and studied in their 2012 paper for arbitrary two-dimensional TQFTs (inspired by the influential previous work by Fröhlich-Fuchs-Runkel-Schweigert on rational CFT) also in the case of three-dimensional TQFTs. As a first step they have studied how to extract the data of a particular type of tricategory $\mathcal{T}$, namely a Gray category with strict duals, from any three-dimensional TQFT with defects Z. To construct the orbifold completion of $\mathcal{T}$ (or Z) they are now categorifying the notion of a symmetric special Frobenius algebra internal to a pivotal bicategory. This will encode algebraically the necessary invariance under 2-3 and 1-4 Pachner moves in the orbifold construction. In parallel, they are considering examples of Reshitikhin-Turaev type, based on the input data of a modular tensor category.

A project that seeks to capitalise on previous results on orbifold completion in a very different direction is ongoing joint work with Alexander Quintero Vélez. Their initial motivation was the earlier work with Runkel (established in the 2012 paper *Orbifold completion of defect bicategories*, as well as with Ana Ros Camacho in the 2013 paper *Orbifold equivalent potentials*) which state orbifold equivalences between matrix factorisation categories associated to simple singularities. The latter come in an ADE classification, and by results of Kajiura-Saito-Takahashi their orbifold equivalences immediately lift to equivalences between the bounded derived categories of path algebras $\mathbb{C}Q$ of the Dynkin quivers Q associated to the simple singularities. A natural question is whether these derived equivalences can be extended to the Ginzburg algebras of $\mathbb{C}Q$, which are also known to be Calabi-Yau extensions in the sense of Keller. Hence they now study the more general question when an orbifold equivalence in the bicategory of smooth and proper dg algebras over some field can be extended to the Calabi-Yau extension. This project has already advanced significantly, and once the main theorem will be fully established there will by several low-hanging applications to derived geometry and 2d/4d correspondences.

Finally, another major project was initiated with the Phd student Flavio Montiel Montoya, who moved from LMU Munich to Vienna in October 2014. The basic task for this endeavour is to understand the connection between categorifications of $\mathfrak{sl}(n)$ and $\mathfrak{so}(2N)$ link invariants as originally proposed by Khovanov and Rozansky.

Further activities

In the early months of my tenure in Vienna Carqueville drafted a so-called "stand-alone" grant application to the Austrian science foundation FWF. Despite the difficult Austrian budget situation and several cutbacks in federal spending on science, this application was approved in full in early December 2014. The roughly 340 000 € attached to it will be spent on a two-year postdoc position, two three-year Phd positions as well as various scientific visitors and travels of members in the group. Luckily the approval came just in time to advertise the postdoc position during application season, and about 80 candidates applied for this job opening. The first offer went to Gregor Schaumann (currently a postdoc at MPI Bonn); he accepted the offer and will move to Vienna in the fall of 2015.

The only other grant application he drafted in 2014, jointly with Daniel Murfet and Ingo Runkel, was for funds for a workshop on "Higher TQFT and categorical quantum mechanics" to be held at ESI in October 2015. This application was successful too.

Besides Magnus Engenhorst and Alessandro Valentino he also invited Anthony Blanc (ESI and Barcelona), Roberto Volpato (MPI Potsdam), Paul Wedrich (Oxford University), and Wolfgang Wieland (Penn State) to visit ESI and deliver seminar talks. Carqueville himself visited various collaborators at LMU Munich, King's College London, Oxford University, Aarhus University, Hamburg University, Harvard University, the University of Southern California, Warsaw University, and the Simons Center for Geometry and Physics, often also to give seminar and/or colloquium talks. In Vienna, he has given one talk at the string theory seminar of the Technical University of Vienna and two talks in the Katzarkov group seminar.

Prints and preprints contributed

Ilka Brunner, Nils Carqueville, Daniel Plencner, *Discrete torsion defects*, `arXiv:1404.7497`, Communications of Mathematical Physics, (DOI) 10.1007/s00220-015-2297-9, Springer 2015.

EPDI Scholars

The European Post-Doctoral Institute for Mathematical Sciences was founded in October 1995 by the The Institut des Hautes Études Scientifiques (Bures-sur-Yvette, France), The Isaac Newton Institute for Mathematical Sciences (Cambridge, United Kingdom) and The Max-Planck-Institut für Mathematik (Bonn, Germany) with the common goal to encourage the mobility of young scientists on a European scale. In 1999 the membership has been enlarged to include among others the Erwin Schrödinger International Institute for Mathematical Physics (Vienna, Austria). At this time the number of institutes engaged in the pursuit of excellence is eleven.

Each year five laureates are awarded a grant-in-aid which allows them extended research visits at member institutions. In recent years the following EPDI scholars visited the ESI:
David Zmiaikou (Université Paris-Sud, Orsay), 2011,
Hiroshi Ando (Kyoto U), 2012, and

Anthony Blanc (Université de Montpellier II): September 1 - November 30, 2014:

Report

During my three months stay at the ESI, I have worked on several directions on my research project on *categorical geometry*, and have benefited from collaborations with some mathematicians from ESI and the University of Vienna. Before I sum up these several directions, let me recall rapidly the setting of my research in mathematics. As for now, my work follows the categorical geometry programme initiated by Kontsevich et al. in an attempt to study *homological mirror symmetry* via Hodge theoretic techniques (see [kkp]). In this programme, the basic object of study are called *dg-categories* together with the subclass of *saturated dg-categories* which are closer to a nice geometric space like a complex smooth projective variety. We then seek for a so-called noncommutative Hodge structure on the periodic cyclic homology of a saturated dg-category. In my thesis [teze] I defined a new invariant of dg-categories defined over the complex field called *topological K-theory*. This new invariant gives a candidate for defining a rational structure on the periodic cyclic homology of a saturated dg-category – this is the content of the lattice conjecture. The hypothetical rational lattice in homology should be seen as the Betti part of a noncommutative Hodge structure.

I have worked by myself on the following questions:

- Work on the Lattice conjecture. I almost finished the case of a dg-category of quasicoherent sheaves on a Deligne–Mumford stack of the form $[X/G]$ with X a complex quasiprojective variety and G a finite group acting on X. I have developed perspectives for the case of a matrix factorization category.

I have enjoyed the following collaborations:

- Together with Nils Carqueville (Simons junior professor at the University of Vienna), we shared interesting discussions on his work on *topological defects* and its relation to the homotopy theory of dg-categories. More precisely we investigated some questions about the equivariant completion of pivotal bicategories endowed with a bimodule with invertible quantum dimension. In such a situation, Carqueville obtained a separable Frobenius algebra of endomorphisms which permits to express some categories of matrix factorizations as categories of modules over such an algebra, see [nilsdefects].

- Together with Ludmil Katzarkov and Pranav Pandit (both at the University of Vienna), we have pursued our project on the deformation theory of dg-categories and the quest for the infinite generation of some Griffiths group of 3-CY dg-categories. Griffiths groups are abelian groups of cycles on projective varieties – they measures the gap between cycles homologically trivial and cycles algebraically trivial. The semi-topological K-theory and the topological K-theory of dg-categories permit to define a categorical analog of these groups. Moreover Claire Voisin has proven that the second rational Griffiths group of a general deformation of a Calabi–Yau 3-fold is infinite dimensional. We therefore develop a deformation theory of dg-categories and in particular of 3-CY dg-categories to investigate the categorical analog of this statement. We have written down an expression of the deformation functor of a dg-category in terms of the classifying space of group maps from a derived loop scheme to a certain stack of tame automorphisms. This gives an explicit formula for the deformations of a dg-category.

During my stay at the ESI, I have given the following talks:

- A mini-course on "Topological K-theory of complex dg-categories" composed of two sessions at the ESI .
- Two talks on "Approximations of formal moduli problems and deformations of categories" at the seminar organized by F. Haiden and G. Dimitrov at the University of Vienna.

I want to thank the ESI for the warm welcoming and its very good working conditions.

References:

[teze] A. Blanc, Invariants topologiques des Espaces non commutatifs,
arXiv preprint arxiv:1307.6430 (2013), PhD thesis (in french), Universite Montpellier 2.

[nilsdefects] N. Carqueville and I. Runkel, Orbifold completion of defect bicategories,
arXiv preprint arxiv:1210.6363 (2012).

[kkp] L. Katzarkov, M. Kontsevich, and T. Pantev, Hodge theoretic aspects of mirror symmetry,
arXiv preprint arxiv:0806.0107 (2008).

Seminars and colloquia

480 seminar and colloquia talks have taken place at the ESI in 2014.

2014 01 13, J. Stöckler: ”Gabor frames of totally positive functions and splines”

2014 01 13, P. Jaming: ”A dynamical system approach to Heisenberg Uniqueness Pairs”

2014 01 13, Q. Sun: ”The abc-problems for Gabor system”

2014 01 14, F. De Mari: ”Coorbit spaces with voice in a Fréchet space”

2014 01 14, H. Führ: ”Wavelet coorbit theory in higher dimensions”

2014 01 14, M. Pap: ”Fundamental analytic wavelet system for the disc algebra of the unit disc”

2014 01 14, P. Grohs: ”Ridgelet discretization of linear transport equations”

2014 01 14, S. Dahlke: ”Shearlet coorbit spaces: General setting, group theoretical background, trace, and embeddings”

2014 01 15, B. Matei: ”Sets of stable sampling: Constructions and counter-examples”

2014 01 15, E. Cordero: ”Time-frequency analysis of Schrödinger equations with bounded potential”

2014 01 15, J. Romero: ”Deformation of Gabor systems”

2014 01 15, V. Turunen: ”Born-Jordan transform”

2014 01 16, I. Pesenson: ”Space-frequency localized frames on Riemannian manifolds”

2014 01 16, J. Ortega Cerdà: ”Sampling polynomials in $\mathbb{R}^n$”

2014 01 16, W. Bauer: ”Heat flow and Berezin-Toeplitz calculus”

2014 01 16, Y. Lyubarskii: ”On bandlimited Lipschitz functions”

2014 01 17, G. Kerkyacharian: ”Regularity of gaussian processes in a geometrical framework”

2014 01 17, H. Harbrecht: ”Adaptive wavelet boundary element methods”

2014 01 17, O. Hutník: ”Wavelets, analytical function spaces and Toeplitz operators”

2014 01 30, M. Fornasier: ”Consistency of probability measure quantization by means of power repulsion-attraction potentials”

2014 02 02, S. Morrison: ”Progress on small fusion categories”

2014 02 14, J. Morton: ”Towards extended TQFT from higher gauge theory”

2014 02 14, S. Burciu: ”the Grothendieck groups of equivariantized fusion categories”

2014 02 17, A. Valentino: ”Boundary conditions for 3d TQFTs and module categories”

2014 02 17, C. Schommer-Pries: ”Extended topological field theories and tensor categories”

2014 02 17, K. Walker: ”Premodular TQFTs”

2014 02 17, S. Natale: ”On weakly group-theoretical non-degenerate braided fusion categories”

2014 02 18, A. Virelizier: ”3-dimensional HQFTs”

2014 02 18, C. Meusburger: ”Diagrams for Gray categories with duals”

2014 02 18, J. Slingerland: ”Local representations of the loop braid group”

2014 02 18, P. Pandit: ”The topological A-model, spectral networks, WKB-theory and buildings”

2014 02 18, T. Nikolaus: ”Twisted differential cohomology”

2014 02 19, B. Vertman: ”Combinatorial quantum field theory and gluing formula for determinants”

2014 02 19, U. Bunke: ”Differential cohomology theory”

2014 02 19, U. Tillmann: ”Commutative K-Theory and other new generalised cohomology theories”

2014 02 20, M. Zeinalian: ”A concise construction of differential K-theory”

2014 02 20, R. Kashaev: ”Beta pentagon relations”

2014 02 20, T. Strobl: ”Dirac sigma models and gauging”

2014 02 20, U. Schreiber: ”Homotopy-type semantics for quantization”

2014 02 21, D. Bar-Natan: ”A partial reduction of BF theory to combinatorics”

2014 02 21, K. Habiro: ”Kirby calculus for null-homologous framed links in 3-manifolds”

2014 02 21, T. Johnson-Freyd: ”Poisson AKSZ theory and homotopy actions of properads”

2014 02 21, T. Schick: ”Geometric models for higher twisted of K-theory (joint with Andrei Ershov, Saratov)”

2014 02 24, C. Becker: ”Relative differential cohomology and Chern-Simons theory”

2014 02 24, C. Voigt: ”Clifford algebras, Fermions, and categorification”

2014 02 24, I. Runkel: ”Spin from defects in two-dimensional field theory”

2014 02 24, J. Andersen: ”Quantum representations of mapping class groups via geometric quantization of moduli spaces”

2014 02 25, A. Carey: ”A geometric approach to twisted K-homology”

2014 02 25, J. Urs Schreiber: ”Cohomological quantization”

2014 02 25, T. Le: ”The Habiro ring and invariants of 3-manifolds”

2014 02 25, T. Nikolaus: ”T-Duality in K-Theory and elliptic cohomology”

2014 02 26, C. Wockel: ”Topological group cohomology and Chern-Weil Theory”

2014 02 26, M. Völkl: ”The intrinsic eta-invariant and geometrizations”

2014 02 26, N. Carqueville: ”Equivariant completion of defect bicategories”

2014 02 27, A. Laszlo: ”Spectral methods in time evolution of non-linear PDEs and application in study of superradiance”

2014 02 27, C. Sämann: ”On geodesics in impulsive gravitational waves”

2014 02 27, J. Swiezewski: ”Geometrical observables for General Relativity related to distances and angles”

2014 02 27, K. Waldorf: ”String geometry vs. spin geometry on loop spaces”

2014 02 27, M. Scholtz: ”On the existence and properties of helically symmetric systems”

2014 02 27, M. Vasuth: ”Spin-orbit effects in the recoil of binary systems”

2014 02 27, P. Mach: ”Accretion in spacetimes with the cosmological constant”

2014 02 27, R. Svarc: ”Kundt spacetimes: algebraic structure and geodesic deviation”

2014 02 27, S. Moeckel: ”Solutions associated with the point symmetries of the hyperbolic Ernst equation”

2014 02 27, U. Pennig: ”An introduction to I-spaces and a conjecture about K(ku)”

2014 02 28, A. Burtscher: ”Self-gravitating collapse of compressible matter under spherical symmetry”

2014 02 28, A. Sakovich: ”A Jang equation approach to positive mass theorem for asymptotically hyperbolic initial data”

2014 02 28, B. Janssens: ”Representation theory of gauge groups”

2014 02 28, C. Huneau: ”Vacuum constraint equations for asymptotically flat space-times with a translational Killing field.”

2014 02 28, D. Barta: ”Dispersion of gravitational waves in cold spherical interstellar medium”

2014 02 28, D. Fajman: ”Future complete spacetimes with spherical spacelike topology in 2+1- dimensions”

2014 02 28, H. Friedrich: ”Afloat in space, time and water”

2014 02 28, I. Smolić: ”Elusive Effects of Gravitational Chern-Simons Terms”

2014 02 28, J. Wang: ”A Large Data Regime for non-linear Wave Equations”

2014 02 28, K. Kroencke: ”Stability of Einstein Manifolds”

2014 02 28, M. Kahl: ”Wave maps on a wormhole”

2014 02 28, M. Maliborski: ”On the (in)stability of asymptotically anti-de Sitter spacetimes”

2014 02 28, M. Reiris: ”Instability of the extreme Kerr-Newman black-holes”

2014 02 28, R. Beig: ”Upstairs and downstairs: my life with tensors”

2014 02 28, R. Tagne Wafo: ”On the characteristic initial value problem for nonlinear symmetric hyperbolic systems with application to semi-linear wave equations on a Lorentzian manifold”

2014 02 28, T. Bäckdahl: ”Symmetry operators and conserved currents”

2014 02 28, T. Paetz: ”The mass of light cones”

2014 03 01, D. Hilditch: ”Recent progress in the numerical treatment of collapsing gravitational waves”

2014 03 01, G. Toth: ”Test of the weak cosmic censorship conjecture with a charged scalar field and dyonic Kerr-Newman black holes”

2014 03 01, M. Korzyński: ”Backreaction and continuum limit in a closed universe filled with black holes”

2014 03 01, N. Bodendorfer: ”Loop quantum gravity in higher dimensions”

2014 03 01, R. Panosso Macedo: ”Physical properties of perturbed Kerr black holes in ACMC slices”

2014 03 01, S. Szybka: ”Inhomogeneity effect in Wainwright-Marshman space-times”

2014 03 10, A. Gaynutdinov: ”Tensor categories in logarithmic CFTs I”

2014 03 12, A. Gaynutdinov: ”Tensor categories in logarithmic CFTs II”

2014 03 12, G. Masbaum: ”Integral TQFT and applications to quantum representations I”

2014 03 13, G. Masbaum: ”Integral TQFT and applications to quantum representations II”

2014 03 14, A. Gaynutdinov: ”Tensor categories in logarithmic CFTs III”

2014 03 14, A. Semikhatov: ”From conformal field theory to Nichols algebras and back”

2014 03 14, G. Masbaum: ”Integral TQFT and applications to quantum representations III”

2014 03 17, D. Ridout: ”Module categories for affine VOAs at admissible level”

2014 03 17, J. Barrett: ”The geometry of matrices and 2d TQFT”

2014 03 17, N. Geer: ”Non semi-simple $sl(2)$ quantum invariants, Part I: From links to TQFTs”

2014 03 17, Q. Chen: ”Congruent skein relation and LMOV conjectures”

2014 03 18, B. Patureau-Mirand: ”Non semi-simple $sl(2)$ quantum invariants, Part II: 3-manifold invariants”

2014 03 18, D. Adamovic: ”On constructions of logarithmic representations for certain vertex algebras”

2014 03 18, G. Schaumann: ”*-representations for tensor categories”

2014 03 18, M. Schnabl: ”New look at BCFT's from OSFT”

2014 03 19, F. Costantino: ”Non semi-simple $sl(2)$ quantum invariants, Part III: TQFTs and mapping class group representations”

2014 03 19, J. Jacobsen: ”Logarithmic correlations in geometrical critical phenomena”

2014 03 19, S. Merkulov: ”Grothendieck-Teichmüller group and exotic automorphisms of the Lie algebra of polyvector fields”

2014 03 20, C. Blanchet: ”Quantum invariants and spin structures”

2014 03 20, C. Schweigert: ”Invariants for mapping class group actions from ribbon Hopf algebra automorphisms”

2014 03 20, J. Murakami: ”Generalized Kashaev invariants for knots in three-manifolds”

2014 03 20, S. Wood: ”Rational logarithmic extensions of the minimal models and their simple modules”

2014 03 21, A. Gaynutdinov: ”From the deformed Virasoro algebra to Temperley-Lieb algebras”

2014 03 21, A. Lazarev: ”Unimodular homotopy algebras and Chern-Simons theory”

2014 03 21, G. Masbaum: ”All finite groups are involved in the mapping class group”

2014 03 31, A. Olshanskiy: ”Growth and cogrowth in free groups”

2014 03 31, C. Cashen: ”Growth tight actions”

2014 03 31, G. Levitt: ”Vertex and extension finiteness in relatively hyperbolic groups”

2014 03 31, I. Bumagin: ”The conjugacy and the conjugacy search problem in relatively hyperbolic groups”

2014 03 31, J. Macdonald: ”Effective coherence, discrimination, and quasi-convexity”

2014 03 31, Z. Sunic: ”Free groups: from free actions to orders to quasi-characters”

2014 04 01, D. Osajda: ”Graphical small cancellation groups with the Haagerup property”

2014 04 01, M. Bridson: ”Minicourse, Geometry of residually finite groups: Profinite isomorphism problems”

2014 04 01, M. Lohrey: ”Parallel complexity of the compressed word problem in groups”

2014 04 01, P. Schupp: ”Asymptotic properties of computability”

2014 04 01, R. Gilman: ”Groups and complexity theory”

2014 04 01, Y. de Cornulier: ”Minicourse II: Introduction to the space of marked groups”

2014 04 02, A. Minasyan: ”New examples of groups acting on real trees”

2014 04 02, D. Kagan: ”Pseudocharacters, bounded cohomologies and width of verbal subgroups”

2014 04 02, M. Bridson: ”Minicourse I, Geometry of residually finite groups: Profinite isomorphism problems”

2014 04 02, Y. de Cornulier: ”Minicourse II: Introduction to the space of marked groups”

2014 04 03, A. Miasnikov: ”Minicourse I, Geometry of residually finite groups: Exotic residually finite groups”

2014 04 03, J. Gismatulin: ”Approximation of groups by manageable structures - weak sofic and weak hyperlinear groups”

2014 04 03, J. Wilson: ”Metric ultraproducts of finite simple groups”

2014 04 03, N. Romanovskiy: ”Logical aspects of the theory of rigid solvable groups”

2014 04 03, S. Gal: ”Groups generated by finite set of transformations and biinvariant metrics”

2014 04 03, V. Guirardel: ”Mincourse II: Introduction to the space of marked groups”

2014 04 04, A. Miasnikov: ”Minicourse I: Geometry of residually finite groups: Dehn Monsters and even worse”

2014 04 04, A. Vdovina: ”Trivalent expanders and Riemann surfaces”

2014 04 04, F. Dahmani: ”On the conjugacy problem for some automorphisms of free groups”

2014 04 04, L. Pyber: ”Applications of the product theorem”

2014 04 04, O. Kharlampovich: ”Some algorithms for Γ-limit groups for a torsion-free hyperbolic group Γ”

2014 04 04, V. Guirardel: ”Minicourse II: Introduction to the space of marked groups”

2014 04 08, A. Juhasz: ”The isoperimetric function of groups defined by a single positive word”

2014 04 09, A. Duncan: ”Subgroups of the automorphism groups of partially commutative groups (RAAGs)”

2014 04 09, C. Cashen: ”Quasi-isometry invariants from decorated trees”

2014 05 05, L. Oksanen: ”Computational approaches to the Boundary Control method”

2014 05 05, L. Ryshik: ”Waves in weakly random media, I”

2014 05 05, L. Ryzhik: ”Waves in weakly random media, II”

2014 05 05, P. Elbau: ”A Model for Photoacoustic Sectional Imaging”

2014 05 06, J. Garnier: ”Correlation-based imaging with moving sensors”

2014 05 06, L. Ryzhik: ”Waves in weakly random media, III”

2014 05 06, L. Ryzhik: ”Waves in weakly random media, IV”

2014 05 06, T. Widlak: ”Stability in linearized elastography”

2014 05 07, C. Tsogka: ”Signal to Noise Ratio analysis in passive correlation based imaging”

2014 05 07, L. Ryzhik: ”Kinetic models for waves in random media”

2014 05 07, S. Arridge: ”Diffuse Optical and PhotoAcoustic Tomography”

2014 05 08, A. Mamonov: ”Krein-Gelfand-Levitan algorithm for inverse hyperbolic problems via spectrally matched finite-difference grids.Joint with V. Druskin and M. Zaslavsky.”

2014 05 08, M. de Hoop: ”Inverse problem of electroseismic conversion”

2014 05 08, S. Arridge: ”Reconstruction in PhotoAcoustic Tomography, I”

2014 05 08, S. Arridge: ”Reconstruction in Quantitative PhotoAcoustic Tomography, II”

2014 05 09, S. Rotter: ”Controlling waves in complex scattering systems”

2014 05 09, W. Naetar: ”Quantitative photoacoustic tomography with piecewise constant material parameters”

2014 05 12, H. Ammari: ”Emerging imaging approaches in medicine”

2014 05 12, M. Hanke: ”Multi frequency MUSIC for impedance imaging”

2014 05 12, P. Stefanov: ”Traveltime tomography with partial data”

2014 05 12, R. Andreev: ”On simultaneous flux/source identification”

2014 05 13, A. Novikov: ”Imaging of sparse scatterers”

2014 05 13, K. Kalimeris: ”Attenuating models and reconstruction methods in Photoacoustic Imaging”

2014 05 13, L. Borcea: ”Imaging in complex environments”

2014 05 13, M. Moscoso: ”Imaging with sparsity promoting optimization”

2014 05 14, B. Kaltenbacher: ”Regularization by discretization: recent convergence results and multilevel strategies”

2014 05 14, R. Alonso: ”Electromagnetic wave propagation in random waveguides”

2014 05 14, R. Ramlau: ”Inverse Problems in Adaptive Optics”

2014 05 14, V. Druskin: ”Finite-difference Gaussian quadrature rules for Dirichlet-to-Neumann Operators and inverse problems”

2014 05 15, A. Tamasan: ”Uniqueness and nonuniqueness in Current Density Impedance Imaging with one current density information”

2014 05 15, J. Schotland: ”Acousto-Optic Imaging”

2014 05 15, S. Moskow: ”Inverse Born series for the Calderon problem and related inverse problems”

2014 05 19, B. Lang: ”Twisted Quantum Fields in Curved Spacetimes á la C.J. Isham from the point of view of Algebraic Quantum Field Theory”

2014 05 19, C. Fewster: ”Algebraic quantum field theory in curved spacetimes”

2014 05 19, D. Siemssen: ”Global Existence of Solutions of the Semiclassical Einstein Equation on Cosmological Spacetimes”

2014 05 19, J. Zahn: ”Locally covariant charged fields”

2014 05 19, K. Sanders: ”Understanding free electromagnetism in the light of general covariance”

2014 05 19, N. Pinamonti: ”Influence of quantum matter fluctuations on the expansion parameter of timelike geodesics”

2014 05 20, A. Schenkel: ”Abelian quantum gauge theories via differential cohomology”

2014 05 20, C. Gérard: ”Construction of Hadamard states for linearized Yang-Mills equations II”

2014 05 20, G. Collini: ”Fedosov quantization and Quantum Field Theory”

2014 05 20, K. Rejzner: ”Quantum gravity from locally covariant quantum field theory: recent results and new perspectives”

2014 05 20, M. Benini: ”Optimal observables for gauge theories via cohomology with restricted support”

2014 05 20, M. Wrochna: ”Construction of Hadamard states for linearized Yang-Mills equations I”

2014 05 20, R. Verch: ”Hadamard condition, ”local vacuum (S-J) states” and Wick-products”

2014 05 20, T. Hack: ”Quantization of the linearised Einstein-Klein-Gordon system on arbitrary backgrounds and the special case of perturbations in Inflation”

2014 05 21, D. Buchholz: ”The quest for understanding in quantum field theory: A new perspective”

2014 05 21, G. Lechner: ”Localization in Nets of Standard Spaces”

2014 05 21, J. Schlemmer: ”Towards covariant adiabatic renormalization on crossed product spaces”

2014 05 21, K. Rehren: ”Boundary conditions and gauge transformations”

2014 05 21, R. Longo: ”Noncommutative Geometrical Aspects in Conformal Nets”

2014 05 21, S. Alazzawi: ”Construction of O(N)-invariant nonlinear sigma-models”

2014 05 21, S. Hollands: ”Operator Product Expansion Algebra I”

2014 05 22, C. Brouder: ”On the main operations with distributions having a specified wavefront set”

2014 05 22, D. Pastorello: ”Geometric Hamiltonian formulation of Quantum Mechanics on complex projective spaces”

2014 05 22, G. Ruzzi: ”Nets of local algebras and gauge theories”

2014 05 22, I. Khavkine: ”The Calabi complex: a case study in linear dynamical obstructions to isotony”

2014 05 22, J. Holland: ”Operator Product Expansion Algebra II”

2014 05 22, M. Dütsch: ”Massive vector bosons: is the geometrical interpretation as a spontaneously broken gauge theory possible at all scales?”

2014 05 22, P. Martinetti: ”Grand symmetry spectral action and the Higgs mass”

2014 05 22, Y. Dabrowski: ”Functional analytic properties of generalized Hormander spaces of distributions and generalized spaces of microcausal functionals”

2014 05 23, G. Tedesco: ”Multi-local transformations for Fermi fields on the circle”

2014 05 23, P. Lauridsen Ribeiro: ”Causal Wedges: a General Framework”

2014 05 23, Y. Tanimoto: ”Wedge-local fields in integrable models with bound states”

2014 06 02, I. Moffatt: ”Graph Polynomials in Knot Theory”

2014 06 02, I. Moffatt: ”Graph Polynomials in Knot Theory”

2014 06 02, P. Di Francesco: ”Matrix Models and Map Combinatorics”

2014 06 03, I. Moffatt: ”Graph Polynomials in Knot Theory”

2014 06 03, P. Di Francesco: ”Matrix Models and Map Combinatorics”

2014 06 03, P. Di Francesco: ”Matrix Models and Map Combinatorics”

2014 06 04, A. Morin-Duchesne: ”Integrability in the dimer model”

2014 06 04, E. Peltola: ”Multiple SLE pure geometries by means of quantum group techniques”

2014 06 04, P. Di Francesco: ”Matrix Models and Map Combinatorics”

2014 06 04, S. Ramassamy: ”Dimers on rail yard graphs”

2014 06 04, V. Slepukhin: ”Infrared dynamics of the massive φ^4 theory on de Sitter space”

2014 06 05, G. Karssen: ”The galactic center”

2014 06 05, I. Moffatt: ”Graph Polynomials in Knot Theory”

2014 06 05, P. Di Francesco: ”Matrix Models and Map Combinatorics”

2014 06 05, P. Di Francesco: ”Matrix Models and Map Combinatorics”

2014 06 06, I. Moffatt: ”Graph Polynomials in Knot Theory”

2014 06 09, A. Guionnet: ”Loop Equations, Topological Expansions, and Universality in Random Matrix Models I”

2014 06 09, R. Gurau: ”Introduction to Random Tensors I”

2014 06 09, R. Gurau: ”Introduction to Random Tensors II”

2014 06 10, A. Guionnet: ”Loop Equations, Topological Expansions, and Universality in Random Matrix Models II”

2014 06 10, A. Guionnet: ”Loop Equations, Topological Expansions, and Universality in Random Matrix Models III”

2014 06 10, R. Gurau: ”Introduction to Random Tensors III”

2014 06 11, A. Guionnet: ”Loop Equations, Topological Expansions, and Universality in Random Matrix Models IV”

2014 06 12, A. Guionnet: ”Loop Equations, Topological Expansions, and Universality in Random Matrix Models V”

2014 06 12, A. Guionnet: ”Loop Equations, Topological Expansions, and Universality in Random Matrix Models VI”

2014 06 12, R. Gurau: ”Introduction to Random Tensors V”

2014 06 13, R. Gurau: ”Introduction to Random Tensors”

2014 06 16, D. Romik: ”Algebraic and bijective combinatorics in the O(1) loop model: constant term identities and commutation of the transfer matrices”

2014 06 16, F. David: ”Planar maps, circle patterns, conformal point processes and 2D gravity”

2014 06 16, J. Bouttier: ”Distances in random planar maps and discrete integrability”

2014 06 16, N. Stoltzfus: ”Ribbon graph constructions, generating functions and topological rank polynomial applications”

2014 06 17, B. de Tiliére: ”From the critical Ising model to spanning trees”

2014 06 17, B. Duplantier: ”Liouville quantum gravity, KPZ and Schramm-Loewner evolution”

2014 06 17, M. Bousquet-Mélou: ”The Potts model on planar maps”

2014 06 17, R. Behrend: ”Multiply-refined enumeration of alternating sign matrices”

2014 06 18, A. Guttmann: ”Unusual critical behaviour of some lattice and combinatorial models”

2014 06 18, A. Procacci: ”Witness trees in the Moser-Tardos algorithmic Lovász Local Lemma and Penrose trees in the hard-core lattice gas”

2014 06 18, H. Steinacker: ”From matrix models to the theory of fundamental interactions”

2014 06 18, I. Moffatt: ”Ribbon graphs, their polynomials, and delta-matroids”

2014 06 18, J. Scott: ”Laurent expansions for twisted Plücker coordinates via dimer partition functions”

2014 06 20, I. Fischer: ”Extreme diagonally and antidiagonally symmetric alternating sign matrices”

2014 06 20, J. Ellis-Monaghan: ”Graph theoretical expressions for statistical mechanics models”

2014 06 20, V. Kazakov: ”Summing planar graphs in zero, one, two, three and four dimensions”

2014 06 20, X. Viennot: ”Heaps of pieces and 2D Lorentzian quantum gravity”

2014 06 25, R. Volpato: ”Symmetries of N=(4,4) non-linear sigma models”

2014 07 14, D. Oriti: ”Group field theories: the combinatorics of tensor models, the quantum geometry of loop quantum gravity”

2014 07 14, E. Kalfagianni: ”State surfaces in quantum and geometric topology”

2014 07 14, H. Grosse: ”Exact solution of a four dimensional field theory”

2014 07 14, R. Gurau: ”Tensor Models in the large N limit”

2014 07 15, B. Benedetti: ”Local constructions of manifolds”

2014 07 15, C. Male: ”The distribution of traffics of large random matrices”

2014 07 15, R. van der Veen: ”Symplectic properties of ideal triangulations”

2014 07 15, V. Rivasseau: ”Constructive tensor field theory”

2014 07 16, J. Eckmann: ”The dynamics of $2d$- and $3d$-topological glasses”

2014 07 16, R. Loll: ”Causal structure and time in (generalized) CDT quantum gravity”

2014 07 17, B. Collins: ”(Random) Tensors and (Asymptotic) Freeness”

2014 07 17, B. Dittrich: ”Quantum Spacetime Engineering”

2014 07 17, C. Koutschan: ”On the AJ conjecture of connected sums of knots”

2014 07 17, J. Ryan: ”Double scaling in tensor models”

2014 07 18, M. Kahle: ”Phase transitions for homology in random simplicial complexes”

2014 07 18, T. Krajewski: ”Analyticity results for the cumulants in a quartic matrix model”

2014 07 28, G. Galloway: ”Lorentzian causality, I”

2014 07 28, J. Corvino: ”Constraint equations, I”

2014 07 28, M. Mars: ”Introduction to general relativity, I”

2014 07 28, M. Mars: ”Introduction to general relativity, II”

2014 07 28, M. Mars: ”Introduction to general relativity, III”

2014 07 28, R. Beig: ”Introduction to differential geometry, I”

2014 07 28, R. Beig: ”Introduction to differential geometry, II”

2014 07 29, G. Galloway: ”Lorentzian causality, II”

2014 07 29, G. Galloway: ”Lorentzian causality, III”

2014 07 29, G. Holzegel: ”Wave equations on black hole space-times, I”

2014 07 29, H. Ringström: ”The Evolution problem in general relativity, I”

2014 07 29, J. Corvino: ”Constraint equations, II”

2014 07 30, G. Galloway: ”Lorentzian causality, IV”

2014 07 30, H. Ringström: ”The Evolution problem in general relativity, II”

2014 07 30, H. Ringström: ”The Evolution problem in general relativity, II”

2014 07 30, J. Corvino: ”Constraint equations, III”

2014 07 31, G. Holzegel: ”Wave equations on black hole space-times, II”

2014 07 31, G. Holzegel: ”Wave equations on black hole space-times, III”

2014 07 31, H. Ringström: ”The Evolution problem in general relativity, III”

2014 07 31, H. Ringström: ”The Evolution problem in general relativity, IV”

2014 07 31, J. Corvino: ”Constraint equations, IV”

2014 07 31, S. Gillessen: ”The galactic center, I”

2014 08 01, G. Galloway: ”Lorentzian causality, V”

2014 08 01, G. Holzegel: ”Wave equations on black hole space-times, IV”

2014 08 01, G. Holzegel: ”Wave equations on black hole space-times, V”

2014 08 01, H. Ringström: ”The Evolution problem in general relativity, V”

2014 08 01, J. Corvino: ”Constraint equations, V”

2014 08 01, S. Gillessen: ”The galactic center, II”

2014 08 04, M. Morgensten: ”Topological properties in solids probed by experiment”

2014 08 04, N. Read: ”Topological phases of matter: 1. Quantum Hall effect and Laughlin states”

2014 08 04, S. Ryu: ”Periodic table of topological insulators and superconductors: invariants built from Bloch wave functions”

2014 08 04, Y. Avron: ”Platonic quantum Hall effect: Chern number”

2014 08 05, J. Bellissard: ”Noncommutative geometry approach to topological invariants in condensed matter physics (I)”

2014 08 05, N. Read: ”Topological phases of matter: 2. Conformal field theory and non-abelian statistics”

2014 08 05, S. Ryu: ”Periodic table of topological insulators and superconductors: Anderson delocalization at the boundary”

2014 08 05, Y. Avron: ”Platonic quantum Hall effect: Fredholm index”

2014 08 06, C. Marcus: ”Majorana modes in semiconductor nanowires?”

2014 08 06, F. Verstraete: ”Classifying topological states using quantum tensor networks (I)”

2014 08 07, F. Verstraete: ”Classifying topological states using quantum tensor networks (II)”

2014 08 07, J. Bellissard: ”Noncommutative geometry approach to topological invariants in condensed matter physics (II)”

2014 08 07, N. Read: ”Topological phases of matter: 3. p+ip paired states and Majorana zero modes”

2014 08 07, S. Ryu: ”Periodic table of topological insulators and superconductors: K-theory; interactions”

2014 08 08, F. Verstraete: ”Classifying topological states using quantum tensor networks (III)”

2014 08 08, J. Bellissard: ”Noncommutative geometry approach to topological invariants in condensed matter physics (III)”

2014 08 08, X. Wen: ”Quantum entanglement, topological order, and tensor category theory (I)”

2014 08 08, X. Wen: ”Quantum entanglement, topological order, and tensor category theory (II)”

2014 08 11, M. Stone: ”Berry curvature, spin and anomalous velocity”

2014 08 11, X. Wen: ”Quantum entanglement, topological order, and tensor category theory (III)”

2014 08 12, J. Teo: ”Twist liquids and gauging anyonic symmetries”

2014 08 12, T. Hughes: ”Spatial symmetry protected topological phases and geometry”

2014 08 13, E. Prodan: ”The non-commutative geometry of the complex classes of topological insulators: analysis and simulation”

2014 08 13, N. Schuch: ”Topological order and chirality of Projected Entangled Pair States”

2014 08 14, S. Ryu: ”Hydrodynamic effective field theories of topological insulators”

2014 08 14, T. Loring: ”Joint pseudospectra and the K-theory of local energy gaps”

2014 08 18, G. Moore: ”Lecture 1: Quantum symmetries and the 3-fold Way”

2014 08 18, V. Gurarie: ”Hall viscosity, shift, and topological invariants”

2014 08 19, G. Moore: ”Lecture 2: Phases of gapped systems and the 10-fold Way”

2014 08 19, J. Moore: ”Abelian and non-Abelian gauge fields in the Brillouin zone for insulators and metals”

2014 08 20, G. Moore: ”Lecture 3: Free fermions, the Altland-Zirnbauer classification, and Bott periodicity”

2014 08 20, N. Read: ”Hall viscosity”

2014 08 21, G. Moore: ”Lecture 4: K-theory classification and application to topological band theory”

2014 08 21, M. Barkeshli: ”Extrinsic defects and possible new experimental probes of topological order”

2014 08 22, A. Ludwig: ”Spin liquids on the Kagome lattice: chiral topological, and gapless non-Fermi liquid phase”

2014 08 22, P. Hořava: ”Multicritical symmetry breaking and resistivity of strange metals”

2014 08 25, J. Fröhlich: ”The growth of cosmic magnetic fields”

2014 08 25, Z. Gu: ”Classification of symmetry-protected topological phases in interacting fermion and boson systems”

2014 08 26, A. Roy: ”Defects in lattice anyon models”

2014 08 26, H. Schulz-Baldes: ”Indices of Fredholm operators with symmetries”

2014 08 27, D. Haldane: ”Quantum geometry of fractional quantum Hall fluids and other topological matter”

2014 08 27, J. Dubail: ”Tensor network states and chiral states of matter”

2014 08 28, H. Tu: ”Projected entangled-pair states for chiral topological phases”

2014 08 28, M. Lein: ”An exhaustive classification of photonic topological insulators”

2014 08 29, A. Carey: ”Spectral flow and operators with essential spectrum”

2014 08 29, X. Qi: ”Layer construction of 3D topological states and string braiding statistics”

2014 09 01, A. Akhmerov: ”Increasing and decreasing the dimensionality of topological insulators”

2014 09 01, D. Haldane: ”Quantum geometry of the fractional quantum Hall fluids and other topological matter (Part 2)”

2014 09 02, A. Sawicki: ”n-particle statistics on quantum graphs”

2014 09 02, T. Quella: ”Topological phases of fractionalized Majorana fermions (parafermions) in one dimension”

2014 09 03, G. de Nittis: ”Differential geometry for time-reversal symmetric Bloch bundles”

2014 09 03, J. Budich: ”Dissipative Chern insulators”

2014 09 04, J. Fuchs: ”Twist defects in topological multilayer systems”

2014 09 04, K. Duivenvoorden: ”Topological quantum error correcting codes”

2014 09 05, P. Werner: ”Tuning material properties by light”

2014 09 08, A. Altland: ”Quantum criticality of the Anderson insulator”

2014 09 08, J. Avron: ”Braiding fluxes in Pauli Hamiltonians”

2014 09 08, J. Kellendonk: ”Topological interpretation of Levinson’s theorem”

2014 09 08, J. Yngvason: ”Incompressibility estimates in the Laughlin phase”

2014 09 08, R. Kennedy: ”Homotopy theory of topological insulators”

2014 09 08, R. Seiringer: ”Validity of spin wave theory for the quantum Heisenberg model”

2014 09 08, S. Diehl: ”Dissipatively induced quantum phases of atomic fermions”

2014 09 09, A. Huckleberry: ”Constructions in low-dimensional complex geometry related to topological insulators and their symmetry classes”

2014 09 09, J. Bellissard: ”Periodic approximant to aperiodic Hamiltonian”

2014 09 09, K. Flensberg: ”Tunneling spectroscopy of Majorana bound states”

2014 09 09, M. Hermanns: ”Majorana metals and quantum spin liquids”

2014 09 09, P. Fendley: ”Parafermions and topological order”

2014 09 09, R. Egger: ”Topological Kondo effect”

2014 09 09, S. Trebst: ”Chiral spin liquids, network models, and fractional quantum Hall states”

2014 09 10, C. Schweigert: ”Topological surface defects, symmetries and dualities”

2014 09 10, G. Graf: ”Bulk-boundary duality for topological insulators”

2014 09 10, Z. Gu: ”Emergence of $p+\mathrm{i}p$ superconductivity in 2D strongly correlated Dirac fermions”

2014 09 11, A. Akhmerov: ”Breaking Kramers degeneracy by superconducting phase differences”

2014 09 11, A. Rosch: ”Skyrmions and emergent monopoles in chiral magnets”

2014 09 11, I. Bloch: ”Probing and controlling topological Bloch bands using ultracold quantum gases”

2014 09 11, J. Fröhlich: ”Gauge theory of states of matter – old and new”

2014 09 11, R. Bondesan: ”Lattice conformal fields at quantum Hall transitions”

2014 09 11, T. Quella: ”Topological aspects of $\mathrm{SU}(N)$ magnetism and its cold atom realization”

2014 09 11, X. Qi: ”Generalized Kitaev models and slave genons”

2014 09 12, B. Nachtergaele: ”Invariants for gapped ground state phases in dimensions one and higher”

2014 09 12, E. Ardonne: ”Constructing critical spin chains using modular invariance”

2014 09 12, H. Schulz-Baldes: ”Invariants of disordered topological insulators”

2014 09 12, H. Siedentop: ”Dipoles in 2d have infinitely many bound states”

2014 09 12, I. Eremin: ”Proximity-induced magnetization dynamics, interaction effects, and phase transitions on a
topological surface”

2014 09 15, M. Engenhorst: ”Bridgeland stability and BPS states I”

2014 09 16, M. Engenhorst: ”Bridgeland stability and BPS states II”

2014 09 17, M. Engenhorst: ”Bridgeland stability and BPS states III”

2014 09 18, M. Engenhorst: ”Bridgeland stability and BPS states IV ”

2014 09 19, M. Engenhorst: ”Bridgeland stability and BPS states V”

2014 09 22, A. Einav: ”Subadditivity of the entropy on a sphere”

2014 09 22, G. Gallavotti: ”Equivalence of Non-Equilibrium Ensembles and Representation of Friction in Turbulent Flows: The Lorenz 96 Model”

2014 09 22, H. Spohn: ”Equilibrium time correlations for quantum anharmonic chains”

2014 09 22, M. Hauray: ”A quantum jump process modelling decoherence induced by the environment”

2014 09 22, S. Aceituno: ”Anomalous energy transport in FPU-beta chain”

2014 09 23, F. Golse: ”Kinetic models in extended phase space”

2014 09 23, G. Basile: ”Fick’s law for the Lorentz model”

2014 09 23, L. Desvillettes: ”About the structure of Landau’s operator of collision”

2014 09 23, M. Pulvirenti: ”Backward clusters, correlations and wild sums for a hard sphere system in a low density regime”

2014 09 23, T. Bodineau: ”The Brownian motion as the limit of a deterministic system of hard-spheres”

2014 09 24, C. Hainzl: ”On the time-dependent BCS equation”

2014 09 24, J. Sabin: ”The Hartree equation for infinite quantum systems”

2014 09 24, J. Solovej: ”Bogolubov theory at positive temperature”

2014 09 24, M. Lewin: ”Derivation of nonlinear Gibbs measures from many-body quantum mechanics”

2014 09 24, M. Porta: ”Mean-field evolution of fermionic systems”

2014 09 24, P. Antonelli: ”On a class of nonlinear Schrödinger equations with nonlinear damping”

2014 09 24, P. Pickl: ”Mean field limits for gases of large volume”

2014 09 25, A. Bobylev: ”Boltzmann equation and hydrodynamics beyond the Navier-Stokes level”

2014 09 25, J. Lukkarinen: ”Hydrodynamics without scaling limits: thermalization in harmonic particle chains with velocity flips”

2014 09 25, K. Carrapatoso: ”Kac’s program for the Landau equation”

2014 09 25, M. Hadzić: ”On the small redshift limit of steady states of the Einstein-Vlasov system and their stability”

2014 09 25, R. Esposito: ”Stationary solutions to the Boltzmann equation and their hydrodynamic limit”

2014 09 26, J. Lopez Velázquez: ”Singularity formation for kinetic equations with cubic nonlinearities”

2014 09 26, P. Nam: ”Bogoliubov correction to the Hartree dynamics of bosons”

2014 09 26, R. Seiringer: ”Validity of the Bogoliubov Approximation for the Excitation Spectrum of Weakly Interacting Bosons”

2014 10 09, A. Blanc: ”Topological K-theory of dg-categories I”

2014 10 13, B. Osting: ”Spectrally Optimized Point Set Configurations”

2014 10 13, E. Trizac: ”The Wigner Crystal problem for charged bilayers”

2014 10 13, I. Sloan: ”QMC designs and covering of spheres by spherical caps”

2014 10 13, J. Brauchart: ”Covering and Separation for points on the sphere”

2014 10 13, J. Marzo: ”Uniformly bounded sets of orthonormal polynomials on the sphere”

2014 10 13, L. Šamaj: ”Ground-state of charged particles between the walls with dielectric images”

2014 10 13, M. Antlanger: ”The asymmetric Wigner bilayer problem”

2014 10 13, S. Torquato: ”Disordered Energy Minimizing Configurations”

2014 10 13, Y. Su: ”The Next-order Term for Minimal Periodic Riesz Energy Asymptotics”

2014 10 14, B. Simanek: ”Periodic Discrete Energy”

2014 10 14, C. Bertrán: ”Optimal distribution of heat sources in the sphere”

2014 10 14, K. Stolarsky: ”Thinking Outside the Circle”

2014 10 14, L. Bétermin: ”Asymptotic expansion of logarithmic energy on the sphere”

2014 10 14, P. Dragnev: ”Universal lower bounds for potential energy of spherical codes”

2014 10 14, P. Leopardi: ”Discrepancy, separation and Riesz energy of finite point sets on compact connected Riemannian manifolds”

2014 10 14, S. Serfaty: ”Next order asymptotics of large systems with Coulomb and Riesz interactions”

2014 10 15, D. Bilyk: ”The L^2 discrepancy of Fibonacci (and other) lattices”

2014 10 15, H. Cohn: ”Optimal simplices and codes in projective spaces”

2014 10 15, J. Dick: ”Numerical integration on the sphere using quasi-Monte Carlos rules”

2014 10 15, L. Markhasin: ”BMO and exponential Orlicz space estimates of the discrepancy function in arbitrary dimension”

2014 10 15, M. Ullrich: ”Frolov cubature in Besov spaces with mixed smoothness”

2014 10 16, D. de Laat: ”Energy minimization via moment hierarchies”

2014 10 16, D. Khavinson: ”Selected question for polynomials in one and several complex variables”

2014 10 16, F. Narcowich: ”A Zeros Lemma for Riemannian Manifolds”

2014 10 16, F. Theil: ”Periodic minimizers in three dimensions”

2014 10 16, J. Ward: ”Local Bases on Spheres with Applications”

2014 10 16, K. Tran: ”The root distribution of polynomials with a three-term recurrence”

2014 10 16, P. Piovano: ”Wulff shape and isoperimetric characterization of crystals”

2014 10 16, S. Torquato: ”Reformulation of the Covering and Quantizer Problems as Ground States of Interacting Particles”

2014 10 16, Y. Wang: ”Computation of isotropic random fields on spheres via needlets decomposition”

2014 10 17, N. Zoriĭ: ”Minimum Riesz energy problems for a condenser with ”‘touching plates”’”

2014 10 17, R. Kusner: ”Möbius energy of Hopf lins in S^3 and Coulomb electrons on S^2”

2014 10 17, S. Borodachov: ”Asymptotic Results on the Discrete Riesz Minimal Energy and Polarization Problems when the Power of the Potential Equals the Dimension of the Conductor”

2014 10 17, U. Stefanelli: ”Carbon geometries as optimal configurations”

2014 10 17, W. Yu: ”Two-distance tight frames”

2014 10 20, A. Valentino: ”Topological Quantum Field Theory via Higher Category Theory I”

2014 10 21, A. Valentino: ”Topological Quantum Field Theory via Higher Category Theory II”

2014 10 22, A. Valentino: ”Topological Quantum Field Theory via Higher Category Theory III”

2014 10 23, A. Blanc: ”Topological K-theory of dg-categories II”

2014 10 23, A. Valentino: ”Topological Quantum Field Theory via Higher Category Theory IV”

2014 10 24, A. Valentino: ”Topological Quantum Field Theory via Higher Category Theory V”

2014 10 27, E. Bannai: ”Tight Euclidean $t-$designs and tight relative $t-$designs in certain association schemes”

2014 10 27, E. Bannai: ”Tight Euclidean $t-$designs on two concentric spheres”

2014 10 27, F. de Oliveira Filho: ”Optimization methods for packing problems”

2014 10 27, W. Kusner: ”A brief analysis of packing regular pentagons in the plane”

2014 10 27, Y. Kallus: ”High-dimensional random packing lattices: Bravais new world”

2014 10 27, Z. Xiang: ”Tight block designs”

2014 10 28, G. Lazzarini: ”Spherical designs and height function of lattices”

2014 10 28, G. Nebe: ”Automorphisms of extremal lattices”

2014 10 28, J. Bi: ”Sub-Linear Root Detection for Sparse Polynomials Over Finite Fields”

2014 10 28, M. Dutour-Sikiric: ”Practical Computing of Hecke operators”

2014 10 28, P. Gruber: ”On Voronoi type results and problems for lattice packings and kissing numbers”

2014 10 28, R. Coulangeon: ”Computing unit groups of maximal orders using Voronoi algorithm”

2014 10 29, M. Stoyanova: ”Computational algorithms for bounding potential energy of spherical codes and designs”

2014 10 29, O. Musin: ”Extreme problems of sphere packings and irreducible contract graphs”

2014 10 29, P. Boyvalenkov: ”Upper and lower bounds for potential energy of spherical designs”

2014 10 29, W. Yu: ”New bounds spherical two-distance sets and equiangular line sets”

2014 10 30, J. Rossetti: ”Integral Lattices, the isospectral problem and the norm one”

2014 10 30, K. Gröchenig: ”A packing problem in time-frequency analysis”

2014 10 30, L. Fukshansky: ”Well-rounded lattices from algebraic constructions”

2014 10 30, M. Ehler: ”Designs in unions of Grassmannians”

2014 10 30, P. Zeiner: ”Well-rounded sublattices in the plane”

2014 10 30, R. Malikiosis: ”Full spark Gabor Frames in Finite Dimensions”

2014 10 30, Y. Zhu: ”Tight relative 2-designs on two shells in Johnson association schemes”

2014 10 31, A. Bondarenko: ”Strongly regular graphs in metric geometry”

2014 10 31, M. Shub: ”Well-conditioned Polynomials”

2014 10 31, S. Robins: ”Cone theta functions and rational volumes of spherical polytopes”

2014 12 17, I. Ciganović: ”Zelevinsky classification of irreducible unramified representations of the metaplectic group”

2014 12 17, I. Matić: ”Composition series and Jacquet modules method”

ESI Research Documentation

ESI research in 2014: publications and arXiv preprints

The following codes indicate the association of preprints with specific ESI activities:

ABCF = 4th Central european Relativity Seminar
AKM = Geometry of computation in groups
ATV = Combinatorics, geometry, and physics
BC = ESI/EMS/IAMP Summer School on Mathematical Relativity
BDF = Algebraic quantum field theory: Its status and its future
BGS = Minimal energy points, lattices, and designs
FG-Fu = Time-frequency analysis (Follow-up)
FRS = Modern trends in topological quantum field theory
RIT= Research in Teams
RYZ = Topological phases of quantum matter
SBS = Theoretical and applied computational inverse problems
SCH = Scaling limits and effective theories in classical and quantum mechanics
SRF = Senior Research Fellows

THEMATIC PROGRAMMES

Modern Trends in Topological Quantum Field Theory (FRS)

D. Adamovic, G. Radobolja, *Free fields realization of the twisted Heisenberg-Virasoro algebra at level zero and its applications*, `arXiv:1405.1707` [math.QA], FRS.

A. Ballesteros, F. J. Herranz, C. Meusburger, *A (2+1) non-commutative Drinfel'd double spacetime with cosmological constant*, `arXiv:1402.2884` [math-ph], FRS.

Á. Ballesteros, F. J. Herranz, C. Meusburger, P. Naranjo, *Twisted (2+1) ?-AdS algebra, Drinfel'd doubles and non-commutative spacetimes*, `arXiv:1403.4773` [math-ph], FRS.

D. Bar-Natan, Z. Dancso, *Finite type invariants of w-knotted objects II: Tangles, foams and the Kashiwara-Vergne problem*, `arXiv:1405.1955` [math.GT], FRS.

D. Bar-Natan, Z. Dancso, *Finite type invariants of w-knotted objects I: w-Knots and the Alexander Polynomial*, `arXiv:1405.1956` [math.GT], FRS.

C. Becker, *Cheeger-Chern-Simons theory and differential string classes*, `arXiv:1404.0716` [math.DG], FRS.

C. Becker, A. Schenkel, R. J. Szabo, *Differential cohomology and locally covariant quantum field theory*, arXiv:1406.1514 [hep-th], FRS.

A. Beliakova, K. Habiro, A. D. Lauda, M. Živković, *Trace decategorification of categorified quantum sl(2)*, arXiv:1404.1806 [math.QA], FRS.

J. Bhowmick, C. Voigt, J. Zacharias, *Compact quantum metric spaces from quantum groups of rapid decay*, arXiv:1406.0771 [math.OA], FRS.

C. Blanchet, *An oriented model for Khovanov homology*, arXiv:1405.7246 [math.GT], FRS.

C. Blanchet, F. Costantino, N. Geer, B. Patureau-Mirand, *Non semi-simple TQFTs, Reidemeister torsion and Kashaev's invariants*, arXiv:1404.7289 [math.GT], FRS.

C. Blanchet, F. Costantino, N. Geer, B. Patureau-Mirand, *Non semi-simple sl(2) quantum invariants, spin case*, arXiv:1405.3490 [math.GT], FRS.

I. Brunner, N. Carqueville, D. Plencner, *Discrete torsion defects*, arXiv:1404.7497 [hep-th], FRS.

U. Bunke, *The universal eta-invariant for manifolds with boundary*, arXiv:1403.2030 [math. AT], FRS.

U. Bunke, T. Nikolaus, *Twisted differential cohomology*, arXiv:1406.3231 [math.AT], FRS.

S. Burciu, *On Müger's centralizer for a certain class of braided fusion categories*, arXiv: 1405.0240 [math.QA], FRS.

A. Carey, F. Gesztesy, D. Potapov, F. Sukochev, Y. Tomilov, *A Jost-Pais-type reduction of Fredholm determinants and some applications*, arXiv:1404.0739 [math.FA], FRS.

A. Carey, F. Gesztesy, D. Potapov, F. Sukochev, Y. Tomilov, *On the Witten index in terms of spectral shift functions*, arXiv:1404.0740 [math.SP], FRS.

J. Chuang, A. Lazarev, W. H. Mannan, *Cocommutative coalgebras: homotopy theory and Koszul duality*, arXiv:1403.0774 [math.AT], FRS.

F. Costantino, N. Geer, B. Patureau-Mirand, *Some remarks on the unrolled quantum group of sl(2)*, arXiv:1406.0410 [math.QA], FRS.

M. Dadarlat, U. Pennig, *A Dixmier-Douady Theory for strongly self-absorbing C*-algebras II: the Brauer group*, arXiv:1403.1234 [math.OA], FRS.

J. Fuchs, J. Priel, C. Schweigert, A. Valentino, *On the Brauer groups of symmetries of abelian Dijkgraaf-Witten theories*, arXiv:1404.6646 [hep-th], FRS.

K. Habiro, T. Widmer, *Kirby calculus for null-homologous framed links in 3-manifolds*, arXiv: 1404.0282 [math.GT], FRS.

M. Izumi, S. Morrison, E. Peters, N. Snyder , *Subfactors of index exactly 5*, arXiv:1406.2389 [math.OA], FRS.

E. Vernier, J. L. Jacobsen, H. Saleur, *Non compact conformal field theory and the $a_2^{(2)}$ (Izergin-Korepin) model in regime III,* arXiv:1404.4497 [math-ph], FRS.

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R. Kashaev, *Penner coordinates for closed surfaces*, arXiv:1403.0180 [math.GT], FRS.

R. Kashaev, *On beta pentagon relations*, arXiv:1403.1298 [math-ph], FRS.

R. Kashaev, *A simple model of 4d-TQFT*, `arXiv:1405.5763` [math.GT], FRS.

A. Kotov, T. Strobl, *Gauging without initial symmetry*, `arXiv:1403.8119` [hep-th], FRS.

S. Lavau, H. Samtleben, T. Strobl, *Hidden Q-structure and Lie 3-algebra for non-abelian superconformal models in six dimensions*, `arXiv:1403.7114` [math-ph], FRS.

M. Mombelli, S. Natale, *Module categories over equivariantized tensor categories*, `arXiv:1405.7896` [math.QA], FRS.

S. Morrison, K. Walker, *The centre of the extended Haagerup subfactor has 22 simple objects*, `arXiv:1404.3955` [math.CT], FRS.

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J. Murakami, *From colored Jones invariants to logarithmic invariants*, `arXiv:1406.1287` [math.GT], FRS.

S. Natale, E. Pacheco, *Graphs attached to simple Frobenius-Perron dimensions of an integral fusion category*, `arXiv:1403.1247` [math.QA], FRS.

S. Natale, *Crossed actions of matched pairs of groups on tensor categories*, `arXiv:1405.6970` [math.QA], FRS.

S. Novak, I. Runkel, *State sum construction of two-dimensional topological quantum field theories on spin surfaces*, `arXiv:1402.2839` [math.QA], FRS.

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N. Reshetikhin, B. Vertman, *Combinatorial quantum field theory and gluing formula for determinants*, `arXiv:1403.6170` [math-ph], FRS.

G. Schaumann, *Pivotal tricategories and a categorification of inner-product modules*, `arXiv:1405.5667` [math.QA], FRS.

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U. Schreiber, *Quantization via Linear homotopy types*, `arXiv:1402.7041` [math-ph], FRS.

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K. Waldorf, *String geometry vs. spin geometry on loop spaces*, `arXiv:1403.5656` [math.DG], FRS.

Combinatorics, Geometry and Physics (ATV)

O. Bernardi, M. Bousquet-Mélou. *Counting coloured planar maps: differential equations*, ATV.

S. Chmutov, F. Vignes-Tourneret. *Partial Duality of Hypermaps*; `arXiv:1409.0632`, ATV.

S. Dartois, *A Givental-like Formula and Bilinear Identities for Tensor Models*, `arXiv:1409.5621`, ATV.

F. David, *The Formalism of Quantum Mechanics: an Introduction*. Vol. 893. Lecture Notes in Physics. Springer, 2015. VII+157pp. ATV

B. Duplantier, A. Guttmann, *The critical exponent for self-avoiding bridges*, ATV.

K. Ebrahimi-Fard, F. Patras, *Cumulants, free cumulants and half-shuffles* `arXiv:1409.5664`, ATV.

J. Ellis-Monaghan, I. Moffatt, *The Las Vergnas Polynomial for embedded graphs*, `arXiv:1311.3762v2` (2014), ATV.

J. A. Ellis-Monaghan, I. Moffatt, *A note on recognizing an old friend in a new place: list coloring and the zero-temperature Potts model*,`arXiv:1406.5532`, ATV.

É. Fusy, A. Tanasa, *Asymptotic expansion of the multi-orientable random tensor model*, `arXiv:1408.5725`, ATV.

R. Gurau, T. Krajewski, *Analyticity results for the cumulants in a random matrix model*, `arXiv:1409.1705`, ATV.

E. Kalfagianni, C. Ruey Shan Lee, *Crosscap numbers and the Jones polynomial*, `arXiv:1408.4493`, ATV.

C. Koutschan, E. Suazo, S. K. Suslov, *Multi-parameter laser modes in paraxial optics*, `arXiv:1407.0730`, ATV.

D. Romik, R. Peled, *Bijective combinatorial proof of the commutation of transfer matrices in the dense O(1) loop model*, `arXiv:1407.5357`, ATV.

Topological Phases of Quantum Matter (RYZ)

P. Werner, R. Sakuma, F. Nilsson, F. Aryasetiawan, *Dynamical screening in* La_2CuO_4, `arXiv:1411.3952`, RYZ.

R. Bondesan, J. Dubail, A. Faribault, Y. Ikhlef, *Chiral* $\mathrm{SU}(2)_k$ *currents as local operators in vertex models and spin chains*, `arXiv:1409.8590`, RYZ.

C. Bourne, A.L. Carey, A. Rennie, *The bulk-edge correspondence for the quantum Hall effect in Kasparov theory*, `arXiv:1411.7527`, RYZ.

C.-K. Chiu, A.P. Schnyder, *Classification of reflection-symmetry-protected topological semimetals and nodal superconductors*, Phys. Rev. B **90** (20), 205136 (2014), RYZ.

S. Yang, T.B. Wahl, H.-H. Tu, N. Schuch, J.I. Cirac, *Chiral projected entangled-pair state with topological order*, `arXiv:1411.6618`, RYZ.

Y. Du, C. Niu, Y. Tian, H. Zhang, *Holographic vortex pair annihilation in superfluid turbulence*, `arXiv:1412.8417`, RYZ.

D. Fiorenza, D. Monaco, G. Panati, $\mathbb{Z}_2$ *invariants of topological insulators as geometric obstructions*, `arXiv:1408.1030`, RYZ.

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R. Kennedy, M.R. Zirnbauer, *Bott periodicity for* $\mathbb{Z}_2$ *symmetric ground states of gapped free-fermion systems*, `arXiv:1409.2537`, RYZ.

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D. Monaco, G. Panati, *Symmetry and Localization in Periodic Crystals: Triviality of Bloch Bundles with a Fermionic Time-Reversal Symmetry*, Acta Applicandae Mathematicae (to appear), DOI 10.1007/s10440-014-9995-8, RYZ.

G. W. Moore, *Quantum Symmetries and K-Theory*, `http://www.physics.rutgers.edu/~gmoore/ViennaLecturesF.pdf`, RYZ.

Minimal Energy Point Sets, Lattices and Designs (BGS)

L. Bétermin, *Renormalized Energy and Asymptotic Expansion of Optimal Logarithmic Energy on the Sphere*, `arXiv:1404.4485`, BGS.

L. Bétermin, P. Zhang, *Minimization of energy per particle among Bravais lattices in* R^2 *: Lennard-Jones and Thomas-Fermi cases*, `arXiv:1402.2751`, BGS.

WORKSHOPS

Geometry and Computation in groups (AKM)

G. Arzhantseva, C. Cashen, J. Tao, *Growth tight actions*, `arXiv:1401.0499`, Pacific Journal of Mathematics, (2015), in press. AKM.

G. Arzhantseva, M. Steenbock, *Rips construction without unique product*, `arXiv:1407.2441`, AKM.

I. Bumagin, *Time complexity of the conjugacy problem in relatively hyperbolic groups*, `arXiv:1407.4528` , AKM.

C. Cashen, G. Levitt, *Mapping tori of free group automorphisms, and the Bieri-Neumann-Strebel invariant of graphs of groups*, `arXiv:1412.8582`, AKM.

C. H. Cashen, J. Tao, *Growth Tight Actions of Product Groups* `arXiv:1404.4335`, AKM.

I. M. Chiswell, A. M. W. Glass, J. S. Wilson, *Residual nilpotence and ordering in one-relator groups and knot groups*, Math. Proc. Camb. Phil. Soc. (2015), **158**, 275-288, AKM.

A. Martin, M. Steenbock, *Cubulation of small cancellation groups over free products*, `arXiv:1409.3678`, AKM.

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ESI/EMS/IAMP Summer School on Mathematical Relativity (BC)

P. Suárez-Serrato, R. Torres, *A note on collapse, entropy, and vanishing of the Yamabe invariant of symplectic 4-manifolds*, `arXiv:1408.1586`, Journal of Geometry and Physics, Vol. 86 (2014), pp. 383-391, BC.

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Algebraic quantum field theory: Its status and its future (BDF)

C. Becker, A. Schenkel, R. J. Szabo, *Differential cohomology and locally covariant quantum field theory*, `arXiv:1406.1514`, BDF.

M. Bischoff, Y. Kawahigashi, R. Longo, K.-H. Rehren, *Phase boundaries in algebraic conformal QFT*, `arXiv:1405.7863`, BDF.

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D. Cadamuro, Y. Tanimoto, *Wedge-local fields in integrable models with bound states* `arXiv:1502.01313`, BDF.

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M. Wrochna, J. Zahn, *Classical phase space and Hadamard states in the BRST formalism for gauge field theories on curved spacetime*, `arXiv:1407.8079`, BDF.

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Time-frequency analysis (Follow-up) (FG-Fu)

A. Borichev, Y. Lyubarskii, *Frame constants near critical density for irregular Gaussian Gabor frames*, FG-Fu.

E. Cordero, K. Gröchenig; F. Nicola, L. Rodino. *Generalized Metaplectic Operators and the Schroedinger Equation with a Potential in the Sjoestrand Class*, J. Math. Phys. 55, 081506 (2014); FG-Fu.

S. Dahlke, F. De Mari, E. De Vito, S. Häuser, G. Steidl, G. Teschke, *Different faces of the shearlet group*, FG-Fu.

H.G. Feichtinger, K. Nowak, M. Pap, *Asymptotic boundary forms for tight Gabor frames and lattice localization domains*, `arXiv:1501.05496`, FG-Fu.

I. Pesenson, H. Feichtinger, H. Führ, *Geometric space-frequency analysis on manifolds*, FG-Fu.

M.V. de Hoop, K. Gröchenig, J.L. Romero, *Exact and approximate expansions with pure Gaussian wave packets*, SIAM J. Math. Anal., Vol.46 No.3, (2014) p.2229-2253; FG-Fu.

O. Hutnik, E.A. Maximenko, A. Miskova, *Toeplitz localization operators: Spectral functions density*, FG-Fu.

P. Jaming, K. Kellay, *A dynamical system approach to Heisenberg uniqueness pairs*, to appear in Journal d'Analyse Mathématique, FG-Fu.

M. Pap, *A special voice transform, analytic wavelets and Zernike functions*, survey paper (60 p.), Advances in Imaging and Electron Physics. Vol 188, 2015, FG-Fu.

Theoretical and applied computational inverse problems (SBS)

E. Beretta, M.V. de Hoop, L. Qiu, O. Scherzer, *Inverse boundary value problem for the Helmholtz equation: Multi-level approach and iterative reconstruction*, `arXiv:1406.2391`, SBS.

RESEARCH IN TEAMS (RIT)

L. Funar, *The topology of closed manifolds with quasi-constant sectional curvature*, `arXiv:1406.0327`, RIT.

L. Funar, Y. Neretin, *Diffeomorphisms groups of Cantor sets and Thompson-type groups*, `arXiv:1411.4855`, RIT.

A. Carey, F. Gesztesy, G. Levitina, D. Potapov, F. Sukochev, D. Zanin, *On index theory for non-Fredholm operators: a* $(1+1)$*-dimensional example*, 2014, submitted. RIT.

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A. Carey, F. Gesztesy, G. Levitina, D. Potapov, F. Sukochev, and D. Zanin, *Trace formulas for a* $(1+1)$*-dimensional model operator*, 2014, submitted. RIT.

SENIOR RESEARCH FELLOWS PROGRAMME (SRF)

L. Dabrowski, G. Landi, F. Luef, *Sigma-model solitons on noncommutative spaces*, `arXiv:1501.02331`, SRF.

SIMONS JUNIOR PROFESSOR NILS CARQUEVILLE

I. Brunner, N. Carqueville, D. Plencner, *Discrete torsion defects*, `arXiv:1404.7497`, Communications of Mathematical Physics, (DOI) 10.1007/s00220-015-2297-9, Springer 2015.

ESI research in previous years: additional prints and arXiv preprints

The following papers complement the ESI preprints already taken into account in 2013.

FNP = Teichmüller Theory
HS = Jets and Quantum Fields for LHC and Future Colliders (Thematic Programme 2013)
JS = Advances in the Theory of Automorphic Forms and their L-functions (Workshop 2013)
RIT = Research in Teams 2013
SRF = Senior Research Fellows 2013

L. Funar, M. Nguyen, *On the automorphisms group of the asymptotic pants complex of an infinite surface of genus zero*, `arXiv:1308.6143`, FNP.

A. Banfi, P.F. Monni, G. Zanderighi, *Quark masses in Higgs production with a jet veto*, JHEP **1401**, 097 (2014), `arXiv:1308.4634`, HS.

M. Baumgart, A.K. Leibovich, T. Mehen, I.Z. Rothstein, *Probing Quarkonium Production Mechanisms with Jet Substructure*, JHEP **1411**, 003 (2014), `arXiv:1406.2295`, HS.

T. Becher, G. Bell, *Enhanced non-perturbative effects through the collinear anomaly*, Phys. Rev. Lett. **112**, 182002 (2014), `arXiv:1312.5327`, HS.

B. Dehnadi, A.H. Hoang, V. Mateu, *Charm and Bottom Masses from Sum Rules with a Convergence Test*, `arXiv:1411.5597`, HS.

P. Pietrulewicz, S. Gritschacher, A.H. Hoang, I. Jemos, Vicent Mateu, *Variable-flavor-number scheme for final state jets in thrust*, Phys. Rev. D **90**, 114001 (2014), HS.

A.H. Hoang, D.W. Kolodrubetz, V. Mateu, I.W. Stewart, *C-parameter Distribution at* N^3LL' *including Power Corrections*, `arXiv:1411.6633`, HS.

A.H. Hoang,V. Mateu,P. Pietrulewicz, *Secondary Production of Massive Quarks in Thrust*, `arXiv:1412.6976`, HS.

A.H. Hoang, P. Pietrulewicz, D. Samitz, *Variable Flavor Number Scheme for Final State Jets*, arXiv:1406.5885, HS.

D. Kang, C. Lee, I.W. Stewart, *Analytic Calculation of 1-Jettiness in DIS at $O(\alpha_s)$*, JHEP **1411**, 132 (2014), arXiv:1407.6706, HS.

M. Asgari, J.W. Cogdell, F. Shahidi, *Local Transfer and Reducibility of Induced Representations of p-adic Groups of Classical Type*, arXiv:1412.6191, JS.

J.W. Cogdell, F. Shahidi, T.-L. Tsai, *Local Langlands correspondence for GL_n and the exterior and symmetric square ε – factors*, arXiv:1412.1448, JS.

W.T. Gan, S. Takeda, *On the Howe duality conjecture in classical theta correspondence*, arXiv:1405.2626, JS.

H. Grobner, M. Harris, E. Lapid, *Whittaker rational structures and special values of the Asai L-function*, arXiv:1408.1840, JS.

R. Holowinsky, R. Munshi, Z. Qi, *Character sums of composite moduli and hybrid subconvexity*, arXiv:1409.3797, JS.

D. Jiang, B. Liu, *Fourier coefficients for automorphic forms on quasisplit classical groups*, arXiv:1412.7553, JS.

H.H. Kim, T. Yamauchi, *A Conditional construction of Artin representations for real analytic Siegel cusp forms of weight (2,1)*, Contemporary Mathematics (to appear),JS.

E. Lapid, Z. Mao, *On Whittaker–Fourier coefficients of automorphic forms on unitary groups: reduction to a local identity*, arXiv:1412.4886, JS.

A. Carey, H. Grosse, J. Kaad, *On a spectral flow formula for the homological index*, arXiv:1501.05453, RIT.

W. Ballmann, *Einführung in die Geometrie und Topologie*, Birkhäuser Basel (2015), SRF.

List of all visitors in 2014

736 scientists have visited the ESI in 2014

The following codes indicate the association of visitors with specific ESI activities:

ABCF = 4th Central european Relativity Seminar
AKM = Geometry of computation in groups
ATV = Combinatorics, geometry, and physics
BC = ESI/EMS/IAMP Summer School on Mathematical Relativity
BDF = Algebraic quantum field theory: Its status and its future
BGS = Minimal energy points, lattices, and designs
FG-Fu = Time-frequency analysis (Follow-up)
FRS = Modern trends in topological quantum field theory
IS = Individual guest scientists
RIT= Research in Teams
RYZ = Topological phases of quantum matter
SAB = Scientific Advisory Board
SBS = Theoretical and applied computational inverse problems
SCH = Scaling limits and effective theories in classical and quantum mechanics
SRF = Senior Research Fellows

Abdesselam Abdelmalek, University of Virginia, Charlottesville; 01.06.2014 - 21.06.2014, ATV; 13.07.2014 - 19.07.2014, ATV;
Abdurrahman Amina, U Wien; 31.03.2014 - 04.04.2014, AKM;
Abele Hartmut, TU Wien; 27.02.2014 - 01.03.2014, ABCF;
Adamovic Drazen, University of Zagreb; 16.03.2014 - 22.03.2014, FRS;
Aichelburg Peter C., Universität Wien; 27.02.2014 - 01.03.2014, ABCF;
Aigner Florian, Universität Wien; 28.07.2014 - 01.08.2014, BC;
Akhmerov Anton, Delft U; 31.08.2014 - 11.09.2014, RYZ;
Akila Maram, U of Duesburg-Essen; 07.09.2014 - 13.09.2014, RYZ;
Aladova Elena, Bar-Ilan University; 29.03.2014 - 04.04.2014, AKM;
Alazzawi Sabina, Universität Wien; 19.05.2014 - 23.05.2014, BDF;
Albanese Guglielmo, U degli Studi di Milano; 27.07.2014 - 02.08.2014, BC;
Aledo Juan Angel, U Castilla-La Mancha; 27.07.2014 - 03.08.2014, BC;
Alldridge Alexander, U Cologne; 07.09.2014 - 13.09.2014, RYZ;
Alonso Ricardo, PUC, Rio de Janeiro; 11.05.2014 - 17.05.2014, SBS;
Altland Alexander, U Cologne; 07.09.2014 - 10.09.2014, RYZ;
Ammari Habib, Ecole Normale Supérieure, Paris; 12.05.2014 - 16.05.2014, SBS;
Amoroso Francesco, Universite de Caen; 24.11.2014 - 05.10.2014, TVW;
Andersen Jorgen E., Aarhus University; 22.02.2014 - 03.03.2014, FRS;
Andersson Lars, Albert Einstein Institut, Postdam; 27.02.2014 - 03.03.2014, ABCF;
Ando Hiroshi, IHES, Burres-Sur-Yvette; 28.08.2014 - 18.02.2014, IS;
Andreev Roman, RICAM, Linz; 11.05.2014 - 16.05.2014, SBS;

Antlanger Moritz, TU Wien; 13.10.2014 - 17.10.2014, BGS;
Antonelli Paolo, University of L'Aquila; 20.09.2014 - 27.09.2014, SCH;
Araujo Salcedo Adriana Victoria, U Estadual Paulista Campus de Sao Paulo, Brasil; 27.07.2014 - 02.08.2014, BC;
Ardonne Eddy, Stockholm U; 06.09.2014 - 13.09.2014, RYZ;
Arnold Anton, TU Wien; 22.09.2014 - 26.09.2014, SCH;
Arridge Simon, University College London; 06.05.2014 - 10.05.2014, SBS;
Avron Joseph, Technion, Haifa; 03.08.2014 - 09.08.2014, RYZ; 07.09.2014 - 12.09.2014, RYZ;
Bachler Philip Josef, U Wien; 28.07.2014 - 01.08.2014, BC;
Bachoc Christine, U de Bordeaux; 01.10.2014 - 01.11.2014, BGS;
Bäckdahl Thomas, U Edinburgh; 26.02.2014 - 02.03.2014, ABCF;
Bagrets Dmitry, U Colonge; 07.09.2014 - 13.09.2014, RYZ;
Bahns Dorothea, Universität Göttingen; 19.05.2014 - 23.05.2014, BDF;
Balasin Herbert, TU Wien; 27.02.2014 - 01.03.2014, ABCF;
Balasubramanian Kallupalam Moulik, Rutgers University; 25.07.2014 - 02.08.2014, BC;
Bannai Eiichi, Shanghai Jiao Tong University ; 12.10.2014 - 01.11.2014, BGS;
Bannai Etsuko, Kyushu University; 12.10.2014 - 01.11.2014, BGS;
Bar-Natan Dror, U of Toronto; 15.02.2014 - 22.02.2014, FRS;
Barsukow Wasilij, MPI, Garching; 27.07.2014 - 02.08.2014, BC;
Barta Daniel, Wigner Research Centre of Physics, Budapest; 27.02.2014 - 02.03.2014, ABCF;
Barkeshli Maissam, UC, Santa Barbara; 03.08.2014 - 24.08.2014, RYZ;
Barrett John, U Nottingham; 16.03.2014 - 25.03.2014, FRS;
Basile Giada, U La Sapienza, Rome; 21.09.2014 - 26.09.2014, SCH;
Bauer Wolfram, U Göttingen; 14.01.2014 - 18.01.2014, FG-FU;
Bayer Dominik, Institut f. Schallforschung; 13.01.2014 - 17.01.2014, FG-FU;
Becker Christian, U Potsdam; 15.02.2014 - 28.02.2014, FRS;
Beckus Siegfried, Friedrich-Schiller-U of Jena; 24.08.2014 - 05.09.2014, RYZ;
Behrend Roger, Cardiff University; 08.06.2014 - 21.06.2014, ATV;
Beig Robert, Universität Wien; 27.02.2014 - 01.03.2014, ABCF; 28.07.2014 - 01.08.2014, BC;
Beil Sabine, U Vienna; 16.06.2014 - 20.06.2014, ATV;
Belhachmi Zakaria, Université de Haute-Alsace, Mulhouse ; 05.05.2014 - 17.05.2014, SBS;
Bell Michael, Duke University, Durham, NC, USA; 27.07.2014 - 02.08.2014, BC;
Bellissard Jean, Georgia Institute of Technology; 03.08.2014 - 12.09.2014, RYZ;
Beltran Carlos, U de Cantabria; 12.10.2014 - 18.10.2014, BGS;
Benatti Fabio, University of Trieste; 10.12.2014 - 13.12.2014, IS;
Benedetti Bruno, FU Berlin; 12.07.2014 - 30.07.2014, ATV;
Benedikter Niels, U Zürich; 21.09.2014 - 26.09.2014, SCH;
Benini Marco, U Pavia; 18.05.2014 - 23.05.2014, BDF;
Berg Soeren Lennart, TU Berlin; 09.10.2014 - 19.10.2014, BGS;
Bering Klaus, Masaryk University, Brno; 21.02.2014 - 21.02.2014, FRS;
Berlai Federico, U Vienna; 31.03.2014 - 10.04.2014, AKM;
Bernard Denis, ENS, Paris; 04.04.2014 - 06.04.2014, SAB;
Bernardi Olivier, Brandeis University, Waltham; 01.06.2014 - 14.06.2014, ATV;
Betermin Laurent, U Paris-Est; 11.10.2014 - 17.10.2014, BGS;
Bhupendra Mishra, Copernicus Astronomical Center, Warsaw; 27.07.2014 - 02.08.2014, BC;
Bi Jingguo, Tsinghua University; 26.10.2014 - 31.10.2014, BGS;
Bilyk Dmytro, U Minnesota; 12.10.2014 - 19.10.2014, BGS;
Bischoff Marcel, U Göttingen; 18.05.2014 - 25.05.2014, ATV;
Bishop Michael Anthony, UC Davis; 21.09.2014 - 29.09.2014, SCH;
Bizoń Piotr, Jagiellonian University, Krakow ; 23.02.2014 - 02.03.2014, ABCF;
Bjerre Mette, Aarhus University; 08.03.2014 - 15.03.2014, FRS;
Blanc Anthony, ESI/University of Montpellier 2; 01.09.2014 - 30.11.2014, IS;
Blanchet Christian, U Paris-Diderot; 16.03.2014 - 21.03.2014, FRS;
Bloch Immanuel, Max-Planck-Institute of Quantum Optics, Garching; 10.09.2014 - 11.09.2014, RYZ;
Bobylev Alexander, Keldysh Institute of Applied Mathematics, Moscow; 20.09.2014 - 27.09.2014,

SCH;
Boccato Chiara, U Zürich; 21.09.2014 - 26.09.2014, SCH;
Bodendorfer Norbert, IFT U Warsaw; 26.02.2014 - 03.03.2014, ABCF;
Bodineau Thierry, Ecole Polytechnique CMAP, Palaiseau; 21.09.2014 - 25.09.2014, SCH;
Bondarenko Andrii, U Trondheim ; 12.10.2014 - 31.10.2014, GBS;
Bondesan Roberto, U Cologne; 24.08.2014 - 13.09.2014, RYZ;
Bonetti Luca, CNRS, Orleans; 27.07.2014 - 02.08.2014, BC;
Bonzom Valentin, LIPN, Villetaneuse; 15.06.2014 - 21.06.2014, ATV;
Borcea Liliana, U of Michigan; 03.05.2014 - 17.05.2014, SBS;
Borodachov Sergiy, Towson University; 10.10.2014 - 20.10.2014, BGS;
Bostelmann Henning, University of York; 17.05.2014 - 25.05.2014, BDF;
Bouniaev Mikhail, U of Texas, Brownsville; 26.10.2014 - 30.10.2014, BGS;
Bousquet-Mélou Mireille, CNRS, U de Bordeaux ; 16.06.2014 - 28.06.2014, ATV;
Bouttier Jérémie, CEA Saclay ; 15.05.2014 - 20.06.2014, ATV;
Boyvalenkov Peter, Bulgarian Academy of Sciences; 26.10.2014 - 01.1.2014, BGS;
Bradlyn Barry, Yale U, New Haven; 07.08.2014 - 17.08.2014, RYZ;
Branding Volker, TU Wien; 19.05.2014 - 23.05.2014, BDF;
Brauchart Johann, TU Graz; 07.10.2014 - 01.11.2014, BGS;
Brauner Tomas, TU Vienna; 04.08.2014 - 12.09.2014, RYZ;
Bräunlich Gerhard, Universität Tübingen; 27.07.2014 - 01.08.2014, BC;
Bridson Martin R., University of Oxford; 30.03.2014 - 04.04.2014, AKM;
Brito Irene, U of Minho; 27.07.2014 - 02.08.2014, BC;
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Lampart Jonas, U Paris Dauphine; 21.09.2014 - 26.09.2014, SCH;
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Stiller Michael, U Hamburg; 19.05.2014 - 23.05.2014, BDF;
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