Erwin Schrödinger International Institute
for Mathematics and Physics

ESI / universität
wien

ANNUAL
REPORT
2018

ESI

THE INSTITUTE PURSUES ITS MISSION THROUGH A VARIETY OF PROGRAMMES

THE ERWIN SCHRÖDINGER INTERNATIONAL INSTITUTE FOR MATHEMATICS AND PHYSICS (ESI), founded in 1993 and part of the University of Vienna since 2011, is dedicated to the advancement of scholarly research in all areas of mathematics and physics and, in particular, to the promotion of exchange between these disciplines.

WORKSHOPS with a duration of up to two weeks focus on a specific scientific topic in mathematics or physics with an emphasis on communication and seminar style presentations.

THE JUNIOR RESEARCH FELLOWSHIP PROGRAMME supports external or local graduate students and recent postdocs to work on a project of their own.

THE ESI FREQUENTLY HOSTS GRADUATE SCHOOLS organized by research groups at the University of Vienna on topics in mathematics or physics aimed at local as well as external PhD students.

THEMATIC PROGRAMMES offer the opportunity for a large number of scientists at all career stages to come together for discussions, brainstorming, seminars and collaboration. They typically last between 4 and 12 weeks, and are structured to cover several topical focus areas connected by a main theme. A programme may also include shorter workshop-like periods.

THE SENIOR RESEARCH FELLOWSHIP PROGRAMME aims at attracting internationally renowned scientists to Vienna for visits to the ESI for up to several months. Senior Research Fellows contribute to the scientific training of graduate students and postdocs of Vienna's research institutions by teaching a course and by giving scientific seminars.

THE RESEARCH IN TEAMS PROGRAMME offers support for research teams to carry out collaborative work on specific projects at the ESI in Vienna for periods of one to four months.

DETAILED INFORMATION about all ESI programmes and the respective application procedures and deadlines are available on the ESI website **www.esi.ac.at**

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Preface

The Institute and its Mission

The Erwin Schrödinger International Institute for Mathematics and Physics (ESI), founded in 1993 and part of the University of Vienna since 2011, is committed to the promotion of scholarly research in mathematics and physics, with an emphasis on the interface between them. It is the Institute's foremost objective to advance scientific knowledge in all areas of mathematics and physics and to create an environment where scientists can exchange ideas and fruitful collaborations can unfold. The best way of achieving this goal is to ensure that the ESI continues to interweave leading international scholars, both in mathematics and physics, and the local scientific community. In particular, the research and the interactions that take place at the Institute are meant to have a lasting impact on those who pursue their scientific education in Vienna. The Institute provides a place for focused collaborative research and aims at creating a fertile ground for new ideas.

In the following, we will give a brief overview of the institutional structure of the ESI and the various programmatic pillars of its scientific activities. Thematic programmes form their core, supplemented by workshops, graduate schools and lecture courses given by Senior Research Fellows at the ESI. All activities include strong educational components. Guided by strict scientific criteria and supported by an international Scientific Advisory Board (SAB), the various actual components of the scientific activities of the ESI are chosen on a competitive basis.

The Institute currently pursues its mission in several ways:

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

(b) by organising additional *workshops* which focus on topical recent developments;

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

(d) by setting up *summer/winter schools* for graduate students and postdocs;

(e) by a programme of *Junior Research Fellows* (JRF), which supports graduate students or recent postdocs to work on a project of their own that is either connected to a research direction carried out at the University of Vienna or to an ESI thematic programme; this JRF programme was restarted in January 2016;

(f) by a programme of *Research in Teams* (RiT), which offers groups of two to four *Erwin Schrödinger Institute Scholars* the opportunity to work at the Institute for periods of one to four months;

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

Scientific Activities in 2018

The list of research areas in mathematics and physics covered by the scientific activities of the Erwin Schrödinger Institute in 2018 shows a wide variety. The following thematic programmes took place:

- *Mathematical Aspects of Physical Oceanography*
  January 22 – March 23, 2018
  (org.: Adrian Constantin (U Vienna), George Haller (ETH Zürich), Stephen Monismith (Stanford U), Themistoklis Sapsis (MIT Boston))

- *Quantum Paths*
  April 9 – June 8, 2018
  (org.: Pasquale Calabrese (SISSA, Trieste), Fabian H. L. Essler (Oxford U), Giuseppe Mussardo (SISSA, Trieste), Jörg Schmiedmayer (TU Vienna), German Sierra (IFT Madrid), Frank Verstraete (U Vienna))

- *Numerical Analysis of Complex PDE Models in the Sciences*
  June 11 – August 17, 2018
  (org.: Annalisa Buffa (EPFL Lausanne), Thomas Y. Hou (Caltech), J.Markus Melenk (TU Vienna), Ilaria Perugia (U Vienna), Christoph Schwab (ETH Zürich))

- *Bivariant K-theory in Geometry and Physics*
  November 5 – 30, 2018
  (org.: Alan Carey (ANU, Canberra), Harald Grosse (U Vienna), Bram Mesland (U Bonn), Adam Rennie (U Wollongong), Walter van Suijlekom (Radboud U Nijmegen))

A detailed account of these thematic programmes is given in subsequent sections of this report.

In addition to thematic programmes, several workshops and conferences took place at the ESI in 2018, complemented by visits of individual scholars who collaborated with scientists of the University of Vienna and the local community. Here is a list of these activities:

- *Mathematical Challenges of Structured Function Systems*
  March 19 – 23, 2018
  (org.: Maria Charina (U Vienna), Karlheinz Gröchenig (U Vienna), Mihai Putinar (UC, Santa Barbara), Joachim Stöckler (TU Dortmund))

- *Matrix Models for Noncommutative Geometry and String Theory*
  July 9 – 13, 2018
  (org.: Denjoe O'Connor (Dublin Inst. for Advanced Studies), Jun Nishimura (KEK, Tsukuba, J), Harold Steinacker (U Vienna), Asato Tsuchiya (Shizuoka U))

- *New Trends in the Variational Modeling of Failure Phenomena*
  August 20 – 24, 2018
  (org.: Elisa Davoli (U Vienna), Manuel Friedrich (U Münster), Riccardo Scala (U Lisbon))

- *Geometric Correspondences of Gauge Theories*
  August 27 – September 07, 2018
  (org.: Giulio Bonelli, Ugo Bruzzo, Jacopo Stoppa, Alessandro Tanzini (all: SISSA, Trieste), Maxim Zabzine (U Uppsala), local organizer: Harald Grosse (U Vienna))

- *Moonshine*
  September 10 – 14, 2018
  (org.: John Duncan (Emory U, Atlanta), Anne Taormina (Durham U), Katrin Wendland (U of Freiburg), Timm Wrase (TU Vienna))

- *Rigidity and Flexibility of Geometric Structures*
  September 24 – 28, 2018
  (org.: Georg Nawratil (TU Vienna), Anthony Nixon (Lancaster U), Josef Schicho (JKU Linz), Brigitte Servatius (Worcester Polytechnic Inst.))

- *E-CAM State-of-the Art Workshop: Large Scale activated Event Simulations*
  October 1 – 3, 2018
  (org.: Peter Bolhuis (U of Amsterdam), Christoph Dellago (ESI, U Vienna), Gerhard Kahl (TU Vienna))

- *Advances in Chemical Reaction Network Theory*
  October 15 – 19, 2018
  (org.: Gheorghe Craciun (U Wisconsin-Madison), Elisenda Feliu (U Copenhagen), Josef Hofbauer (U Vienna), Stefan Müller (U Vienna))

- *Concepts of Probability in the Sciences*
  October 29 – 30, 2018
  (org.: Christoph Dellago (ESI, U Vienna), Wolfgang Reiter (ESI, U Vienna), Jakob Yngvason (ESI, U Vienna))

- *Analysis and CR Geometry*
  December 10 – 14, 2018
  (org.: Shif Berhanu (Temple U), Anne-Katrin Gallagher (Oklahoma State U), Bernhard Lamel (U Vienna), Takeo Ohsawa (Nagoya U))

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

In the winter term Eric Bergshoeff (U Groningen) gave a course on *Applied Newton-Cartan Geometry*. In the summer term Francis Filbet (Université Paul Sabatier, Toulouse III & Institut Universitaire de France) gave a course on *Introduction to Kinetic Theory: The Boltzmann Equation*.

Established in 2012, the *Research in Teams Programme* provides the opportunity for research teams of a few people to work at the Institute in order to concentrate on new collaborative research in mathematics and physics. The interaction between the team members is a central component of this programme. The following two research teams worked at the ESI in 2018:

- Armengol Gasull (U Autonoma de Barcelona), Anna Geyer (Delft U of Technology), Víctor Mañosa (U Politecnica de Catalunya), *Traveling Waves in Hydrodynamics*, July 1 – 31, 2018.

- Hamid Ahmadinezhad (Loughborough U), Ivan Cheltsov (U of Edinburgh), Jihuan Park (Pohang U of Science and Technology), Konstantin Shramov (Steklov Institute, Moscow), *Finite Insoluble Subgroups of the Space Cremona Group*, August 1 – 31, 2018.

In the year 2018 the following Junior Research Fellows visited the ESI to work on their research project:

- Vikas S. Krishnamurthy, *New Frontiers in Applied Complex Analysis: Compressible Fluid Flows in multiply connected Domains*, April 1 – July 31, 2018.

- Layne Frechette, *Theory and Simulation of a Microscopic Model for Cation Exchange in Nanocrystals*, April 9 – May 11, 2018.

- Bert Verbeke, *A Unified Study of Geometrically and Topologically interesting Automorphisms of Lie Algebras*, May 26 – July 1, 2018.

- Zahra Mirzaiyan, *Soft Hair on Black Holes in Four Dimensional Space-Times*, July 1 – October 31, 2018.

- Matteo Cavaleri, *Approximations and computations in infinite groups*, July 15 – September 15, 2018.

- Angela Carnevale, *Enumeration of Matrices, Hyperoctahedral Groups, and Generating Functions*, July 30 – November 30, 2018.

- Andreas Zöttl, *Coarse-grained hydrodynamic simulations of driven colloids in macromolecular polymer solutions*, September 1 – December 31, 2018.

- Mattia Ornaghi, *Dg enhancements via A ∞-categories*, October 15, 2018 – February 15, 2019.

- Jarrod Lewis Williams, *Exact and Approximate Killing Symmetries in General Relativity: Dain Invariants on Black Hole Spacetimes and Integrability of KID Equations*, November 1, 2018 – February 28, 2019.

The reports of the Mattia Ornaghi and Jarrod Lewis Williams will be part of the annual report 2019.

In 2018 the Erwin Schrödinger Institute hosted also a joint event of the Vienna Doctoral Schools Mathematics and Physics:

- *Science Meets: Medicine* on May 29, 2018 was the second joint meeting of the VDS Mathematics and VDS Physics.

The Institute's Management

Kollegium

The ESI is governed at the organizational and scientific level by a board ('Kollegium') of six scholars, all faculty members of the University of Vienna. Their term of office is three years. The members of this board are appointed by the President (Rektor) of the University after consultations with the Deans of the Faculties of Physics and Mathematics. There was no change in the composition of the Kollegium of the ESI in 2018. Hence, in the period January 1 - December 31, 2018, the Kollegium consisted of A. Constantin (Mathematics), C. Dellago (Physics), M. Eichmair (Mathematics), S. Fredenhagen (Physics), A. Hoang (Physics), I. Perugia (Mathematics). All members of the Kollegium still act as professors at the University.

At the operational level, the ESI is managed by the director supported by two deputy directors. This team of directors is proposed by the Kollegium and appointed by the Rector of the University. Currently, the ESI is managed by Christoph Dellago (Director), André H. Hoang (Deputy Director) and Ilaria Perugia (Deputy Director).

Scientific Advisory Board

The scientific activities of the ESI are supervised by the Scientific Advisory Board (SAB), composed of leading scientists. The SAB also reflects the international ties which are essential for the ESI. In 2018, the SAB consisted of: Denis Bernard (ENS Paris), Mirjam Cvetic (U of Pennsylvania, Philadelphia), Helge Holden (U Trondheim) [chair], Daniel Huybrechts (U Bonn), Christian Lubich (U Tübingen), Stefano Ruffo (SISSA, Trieste), Catharina Stroppel (U Bonn), and Martin Zirnbauer (U Cologne).

The composition of the SAB of the ESI changed by the end of the year 2018. After two terms of office, Denis Bernard, Helge Holden, and Daniel Huybrechts have retired from the Board. The Institute is very grateful to them for many years of valuable advice and support. Special thanks go to Helge Holden for chairing the SAB in the years 2016 - 2018. Alberto Bressan (Penn State U), Domenico Giulini (U Hannover) and Gerhard Huisken (U Tübingen) joined the Board on January 1, 2019, as new members.

Administration

The composition of the administrative staff of the ESI changed in 2018. Sophie Kurzmann left the Institute and we would like to thank her for her excellent work during the last three years. Renate Zechner joined the administration team, which continues to work with customary efficiency for our visitors, research fellows and scientific staff.

Christoph Dellago   May 23, 2019

ESI Director

Erwin Schrödinger International Institute for Mathematics and Physics

The ESI in 2018: facts and figures

Management and Administration:

Director: Christoph Dellago

Kollegium: Christoph Dellago (Director), André H. Hoang (Deputy Director), Ilaria Perugia (Deputy Director), Adrian Constantin, Michael Eichmair, Stefan Fredenhagen

Administration: Sophie Kurzmann, Maria Marouschek, Beatrix Wolf (Head), Renate Zechner

Computing and networking support: Sascha Biberhofer, Thomas Leitner

International Scientific Advisory Board in 2018:

Denis Bernard (ENS Paris)	Christian Lubich (U Tübingen)
Miriam Cvetic (U Pennsylvania, Philadelphia)	Stefano Ruffo (SISSA, Trieste)
Helge Holden (U Trondheim) [chair]	Catharina Stroppel (U Bonn)
Daniel Huybrechts (U Bonn)	Martin Zirnbauer (U Cologne)

Budget and visitors: In 2018 the support of ESI received from the University of Vienna amounted to €790 000. In addition, the ESI obtained a total of €154 159 in third party funds.

The total amount spent in 2018 on scientific activities was €538 049 while the expenditures for administration (mainly salaries) and infrastructure (mainly rent) amounted to €486 509.

The total number of scientists visiting the Erwin Schrödinger Institute in 2018 was 763, see pages 104 – 120.

ESI research documentation: Starting from January 2013, the ESI research output is tracked using the published articles and the arXiv database. 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 2018 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 2018 is 102 [related to the activities in 2018: 87, related to the activities in previous years: 15], see pages 97 – 103 for details.

Scientific Reports

Main Research Programmes

Mathematical Aspects of Physical Oceanography

Organizers: Adrian Constantin (U Vienna), George Haller (ETH Zurich), Stephen Monismith (Stanford U), Themistoklis Sapsis (MIT Boston)

Dates: January 22 – March 23, 2018

Budget: ESI € 36 560,
third-party funds: € 6 300 to cover the travel costs of some participants and € 736 for the social dinner during the workshop.

Report on the programme

Several themes were discussed during the programme, chosen among currently very active research areas of physical oceanography (for example, Lagrangian coherent structures and Ekman-type flows) and a substantial body of theory to aid in the interpretation of observations is about to be developed. Also, several challenging problems with good perspectives of steadily advancing the state-of-the-art were identified and some research collaborations were initiated. A very gratifying aspect was the successful interdisciplary communication (between people with backgrounds in mathematics, physics or engineering) that took place, permitting interplays between theory and observation, with analytical and computational aspects often intertwined and mutually reinforcing each other. We believe that the programme succeeded in presenting the state-of-the-art of the interdisciplinary field of physical oceanography, as well as in setting forth some new promising directions of research. There is an underspending due to the fact that some of the more applied researchers that we hoped that will come had, by the time that the official invitations were sent out, already a fully booked schedule. This is due to a different planning culture in engineering (as opposed to the typical expertise of the ESI with researchers from mathematical/physical research institutions), where research trips have to be planned months in advance.

Activities

The programme workshop took place in the period March 12 – 16 and featured talks by mathematicians as well as by experts in oceanography, covering theoretical topics as well as studies of field data and numerical simulations. Colloquium talks were scheduled in the other weeks of the programme (typically on Wednesdays) and a mini-course (aimed at graduate students) was

organised, with lectures by Prof. R. S. Johnson ("Physical oceanography: the applied mathematical approach"). After discussions with several graduate students and younger researchers that were in the audience, it turned out that the best format is to have these lectures on the same afternoon (Wednesday, February 2), rather than in separate weeks.

Specific information on the programme

Several PhD-students (S. Haziot from Vienna, D. Amann from Linz, M. Kluczek from Cork, A. Compelli from Dublin) participated intensively to the workshop, listening to several talks and discussing with some of the visiting researchers. Two of them started even research collaborations on this occasion. Also, a number of young and promising researchers established contacts with experts from abroad (for example, K. Marynets from Vienna initiated a joint research project with C. I. Martin from University College Cork, Ireland).

Outcomes and achievements

Several scientific collaborations were started during this programme. For example, a group from the University of Vienna started working on a topic related to equatorial flows with a group at the Hebrew University of Jerusalem, and another group in Vienna did begin a joint research endeavour on Lagrangian aspects of ocean flows with experts from the University of Oslo. Furthermore, useful contacts were established between people with expertise in theoretical aspects (R. S. Johnson from Newcastle) and experimentalists (M. Vincze from Budapest). The open discussions that took place during the workshop prompted two of the co-organisers (A. Constantin and G. Haller) to plan for a follow-up workshop, that would facilitate further fruitful interactions between some of the participants.

List of talks

Main Workshop, March 12 – 16, 2018

Roger Samelson	Poleward undercurrents on eastern ocean boundaries
Themistoklis Sapsi	Quantification and prediction schemes for extreme events in turbulent dynamical systems
Kayo Ide	Incorporating prior knowledge in observability-based path planning for ocean sampling
Francisco J. Beron-Vera	Lagrangian geographies
Göran Broström	Drift in the upper ocean
Mattia Serra	Material Transport Barriers in Geophysical Flows
George Haller	Material barriers to diffusive and stochastic transport
Tamas Tél	Experimental evidence for the water-holding property of three-dimensional vortices
Miklos Vincze	Wind-induced resonant thickening of the oceanic Ekman-layers: an experimental analysis
M. Josefina Olascoag	Lagrangian climatologies
Robin S. Johnson	Ekman-type flows as a shallow-water approximation of the Navier-Stokes equation for a spherical, rotating Earth
Anatoly Abrashkin	Wind-generated equatorial Gerstner-type waves
Eric Vanden-Eijnden	Extreme events, tail statistics, and large deviation theory in geophysical flows
Dimitrios Giannakis	Extraction and prediction of coherent patterns in incompressible flows through space-time Koopman analysis
Darren Crowdy	New analytical solutions for vortical flows on the plane and the surface of a sphere

Karima Khusnutdinova	Ring waves in a stratified fluid over a depth-dependent parallel shear flow
Michal Branicki	Path-based and probabilistic measures of expansion rates in stochastic flows and their applications to Lagrangian transport
Brian Arbic	Global modeling of the oceanic internal gravity wave spectrum
Mohammad Farazmand	Optimal initial condition of passive tracers for their maximal mixing in finite time
Peter Koltai	From large deviations to transport semidistances: coherence analysis for finite Lagrangian data
Daniel Karrasch	A geometric Lagrangian perspective on advection-diffusion and coherent structures
Paul Dellar	Noncanonical Hamiltonian structure of the shallow water equations with complete Coriolis force
Stephen Monismith	Salinity intrusion in Northern San Francisco Bay: Observations and models

Individual talks

Paul J. Dellar	A variational derivation of β-plane approximations for flow on rotating spheres
Geoffrey Vallis	A Theory for the Meridional Overturning Circulation of the Ocean
David Marshall	Geometry and Energetics of Mesoscale Ocean Eddies and Their Rectified Impact on Climate
Amin Chabchoub	Unstable wave packets propagating in finite and shallow water regimes
Alberto Bressan	Global solutions to the Burgers-Hilbert equation
Andre Nachbin	Capturing the flow structure beneath water waves
Robin S. Johnson	Physical oceanography: the applied mathematical approach
Hisashi Okamoto	Existence proof of solutions of fluid mechanical equations via interval analysis
Nathan Paldor	How do large-scale flows in the ocean become geostrophic?
Jan Erik. H. Weber	Lagrangian approach to wave-induced flow in a viscous rotating ocean
Kai Håkon Christensen	The importance of wave-current interactions in operational oceanography

Publications and preprints contributed

A special issue of the peer-review journal *Deep-Sea Research Part II: Topical Studies in Oceanography* was devoted to papers that reflect the scientific discussions that took place during this programme. The special issue was published in February 2019 as volume 160, DOI: https://doi.org/10.1016/j.dsr2.2019.01.004.

A. Constantin, G. Haller, *Preface: Dynamics of ocean waves and currents*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 3-6, https://doi.org/10.1016/j.dsr2.2019.01.004.

A. Abrashkin, *Generalization of Cauchy invariants for equatorial β-plane flows*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 1-2, https://doi.org/10.1016/j.dsr2.2019.01.003.

B. Basu, *Some numerical investigations into a nonlinear three-dimensional model of the Pacific equatorial ocean flows*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 7-15.

T. Bozóki, L. Czelnai, A.Horicsányi, A. Nyerges, A. Pál, J. Pálfy, M. Vincze, *Large-scale ocean circulation in the Southern Hemisphere with closed and open Drake Passage – A laboratory minimal model approach*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 16-24, https://doi.org/10.1016/j.dsr2.2019.01.005.

A. Constantin, G. Haller, *Large-scale oceanic currents as shallow-water asymptotic solutions of the Navier-Stokes equation in rotating spherical coordinates*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 32-40, https://doi.org/10.1016/j.dsr2.2018.12.007.

A. C. Compelli, R. I. Ivanov, C. I. Martin, M. D. Todorov, *Surface waves over currents and uneven bottom*, Elsevier, Deep-Sea Research Part II 160 (2019) 25-31, DOI: https://doi.org/10.1016/j.dsr2.2018.11.004.

D. Henry, *Stokes drift in equatorial water waves, and wave–current interactions*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 41-47.

R.S. Johnson, *Some problems in physical oceanography (including the use of rotating spherical coordinates) treated as exercises in classical fluid mechanics: Methods and examples*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 48-57, https://doi.org/10.1016/j.dsr2.2018.08.010.

K. Marynets, *The Antarctic Circumpolar Current as a shallow-water asymptotic solution of Euler's equation in spherical coordinates*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 58-62, https://doi.org/10.1016/j.dsr2.2018.11.014.

N. Paldor, *Recent advances in linear wave theory on the spherical earth*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 63-67.

J. E. H. Weber, *Lagrangian studies of wave-induced flows in a viscous ocean*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 68-81.

P. Miron, F. J. Beron-Vera, M. J. Olascoaga and P. Koltai, *Markov-chain-inspired search for MH370*, AIP Chaos: An Interdisciplinary Journal of Nonlinear Science, https://aip.scitation.org/journal/cha, DOI: https://doi.org/10.1063/1.5092132.

Invited scientists

Anatoly Abrashkin, Brian Arbic, Biswajit Basu, Francisco Beron-Vera, Michal Branicki, Katharina Brazda, Alberto Bressan, Göran Broström, Amin Chabchoub, Kai H. Christensen, Alan Compelli, Adrian Constantin, Darren Crowdy, Paul Dellar, Nilay Duruk-Mutlubas, Mohammad Farazmand, Anna Geyer, Dimitrios Giannakis, George Haller, Benjamin Harrop-Griffiths, Susanna Haziot, David Henry, Kayo Ide, Rossen Ivanov, Robin Johnson, Daniel Karrasch, William Kessler, Karima Khusnutdinova, Mateusz Kluczek, Florian Kogelbauer, Peter Koltai, Tony Lyons, Calin Martin, David Marshall, Kateryna Marynets, Luc Molinet, Stephen Monismith, Ryan Murray, Andre Nachbin, Hisashi Okamoto, Josefina Olascoaga, Nathan Paldor, Ronald Quirchmayr, Adrian Rodriguez-Sanjurjo, Roger Samelson, Themistoklis Sapsis, Mattia Serra, Tamas Tél, Gareth P. Thomas, Geoffrey K. Vallis, Eric Vanden-Eijnden, Gabriele Villari, Miklos Vincze, Jan Erik Weber, Miles Wheeler.

Quantum Paths

Organizers: Pasquale Calabrese (SISSA, Trieste), Fabian H. L. Essler (Oxford U), Giuseppe Mussardo (SISSA, Trieste), Jörg Schmiedmayer (TU Vienna), German Sierra (IFT Madrid), Frank Verstraete (U Vienna)

Dates: April 9 – June 8, 2018

Budget: ESI € 56 000,
SFB FOQUS € 5 000.

Report on the programme

The goal of the programme was to address the intriguing behaviours of many-body quantum systems in one and two spatial dimensions. These are found in both condensed matter and

cold atom systems and their understanding constitutes one of the main frontiers of modern theoretical physics. The programme focused on several closely related topics:

- **Quantum systems out of equilibrium.** Recent years have witnessed significant progress in understanding the dynamics in isolated, periodically driven, and open many-particle quantum systems. Key questions include relaxation in presence of inhomogeneous initial conditions, realizing new states of matter in periodically driven systems and spreading of information and entanglement after quantum quenches.

- **Cold atomic systems.** These provide a highly tunable setting for studying low dimensional many-particle systems both in and out of equilibrium.

- **Low-dimensional quantum many-particle systems.** These have long been of interest as the presence of pronounced quantum mechanical effects leads to unusual physical behaviours. Key questions concern the roles of frustration, quasi-periodicity and disorder.

- **Quantum integrability.** Exact solutions of integrable models have provided crucial benchmarks for one dimensional systems. Key questions of current interest include the calculation of correlation functions at finite temperature and in the steady state after quantum quenches.

- **Tensor network methods.** Over the last decade there have been impressive developments of the ideas and concepts underlying the Tensor Network approaches. Key questions concern their application to the study of phase transitions in 2+1 dimensional systems and to the description of quantum field theories.

- **Entanglement.** Entanglement measures have proved to be very useful tools both in and out of equilibrium, e.g. by providing universal characterizations of critical and topological phases. Key questions include how to use integrability to calculate entanglement, how to use entanglement to design new effective algorithms for global quantum quenches and how entanglement spreads out of equilibrium.

A key objective was to bring together researchers from a variety of fields in condensed matter physics, cold atom physics and quantum information, and in particular to promote interactions between theorists and experimentalists. Judging by the feedback from the participants the programme was highly successful in this regard.

Activities

"Quantum Paths" started with a one-week conference from 9 - 13 April covering the programme's entire range of topics.

The conference attracted a number of attendees from Vienna and elsewhere and generated lively discussions and interactions in particular between experimentalists (listed in red above) and theorists. Towards the end of the programme we organized a 3-day mini-conference focusing on non-equilibrium dynamics. This took place from May 28 to 30 May and was intended to provide a forum in particular for more junior participants (at graduate student and post-doctoral level) of Quantum Paths.

The second week of the programme focused on non-equilibrium dynamics. It started with an introductory lecture by Prof. Roderich Moessner from the MPI PKS Dresden on Thermodynamics and order beyond equilibrium – from eigenstate thermalisation to time crystals. There were three regular talks by Prof. Juan Garrahan (Nottingham), Prof. Sebastian Will (Columbia) and Dr Jerome Dubail (Nancy).

The focus of week 3 was on non-equilibrium dynamics and on disorder effects. Prof. Victor Gurarie (Boulder) gave an introductory lecture on Quantum particles in a random potential in high dimensions. There were four regular talks by Dr. Stefan Floerchinger (Heidelberg), Prof. Paul Fendley (Oxford), Prof. Sebastian Diehl (Cologne) and Prof. Andrea Gambassi (SISSA, Trieste).

Week 4 was primarily concerned with low dimensional quantum systems. Prof. Andrey Zheludev (ETH) gave an overview lecture on experimental studies of quantum spin chains entitled Low-energy excitations in spin chains and ladders. There were 4 regular talks by Prof. Thierry Giamarchi (Geneva), Prof. Masaki Oshikawa (ISSP Tokyo), Prof. Tetsuo Deguchi (Ochanomizu University) and Dr. Martin Ganahl (Perimeter Institute).

The focus of week 5 was on low dimensional systems and non-equilibrium dynamics. Prof. Gergeley Zarand (Budapest) gave an introduction to Semi-semiclassical theory of one-dimensional non-equilibrium systems. There were talks by Prof. Marcos Rigol (Penn State), Prof. David Weiss (Penn State) and by Prof. Alexei Tsvelik (Brookhaven National Laboratory).

Week 6 focussed on Tensor networks & entanglement. There were talks by Dr Carmen Banuls (MPI Munich), Prof. Anatoli Polkovnikov (Boston University), Dr. Olalla Castro Alvaredo (City University London), Prof. Belen Paredes (LMU Munich) and by Prof. Frank Pollmann (TU Munich).

Week 7 was concerned with integrability and quantum chaos. There were talks by Prof. Tomaz Prosen (Ljubljana), Prof. Aditi Mitra (NYU), Prof. Andreas Klümper (Wuppertal), Dr Joe Bhaseen (King's College London).

Outcomes and achievements

Quantum Paths helped to start new collaborations while providing at the same time an opportunity to continue work on ongoing projects. Some examples are listed below:

OLALLA CASTRO-ALVAREDO had interesting discussions with G. Sierra and B. Paredes on the entanglement content of excited states. Two recent preprints on this topic acknowledge the kind support of ESI. She also was involved in discussions with B. Bertini which led to the initiation of a collaboration relating to the out-of-equilibrium dynamics of the sine-Gordon model, involving him, B. Doyon, I. Scézsényi, M. Kormos and L. Piroli.

JEAN-SEBASTIEN CAUX was in Vienna during the conference week and had some productive discussions with a number of participants, in particular with J. Schmiedmayer about split condensates, prethermalization, higher-point correlation functions, and generalized Hydrody-

namics; with F. Verstraete, about matrix-product state representation for continuous systems, and Floquet dynamics of strongly-correlated systems. He also caught up a collaboration with J. De Nardis.

IGNACIO CIRAC was only present for two days during the conference, had nevertheless time to talk to F. Verstraete, and explained some of the work he is carrying out in Munich. He also talked to D. Bernard about tensor networks, and M. Oberthaler about his experiments on cold atoms.

MARCELLO DALMOTE had interesting discussions with M. Rigol (modular operators off-equilibrium), G. Zarand (lattice gauge theories and anomalous confinement), M. Serbyn (localization in U(1) gauge theories and entanglement spreading). The discussions with M. Rigol have partially motivated a project he has just started on entanglement Hamiltonians of lattice field theories after a quench. Discussions with Dave Weiss on his recently developed optical lattice Rydberg architecture have been extremely useful in view of two entanglement measurements protocols he is developing. Finally he completed a work on interacting crystalline topological insulators that will acknowledge ESI hospitality.

SEBASTIAN DIEHL had discussions with A. Silva, A. Gambassi and R. Moessner on Floquet systems and obtained valuable feedback on a work that was in preparation regarding a fluctuation induced first order phase transition that occurs in high dimensional Floquet systems as a consequence of the absence of energy conservation. He also interacted with F. Essler on integrability of fermionic systems undergoing a Lindblad evolution into topological states and with J. Schmiedmayer on weak measurements of quantum wires in order to determine temporal multipoint correlation functions.

ROSARIO FAZIO mostly worked on the problem of broken-symmetry phases with oscillating macroscopic order parameters, thus breaking continuous time-translational symmetry. This problem is relevant for the upcoming generation of circuit QED arrays experiments, for Floquet time crystals and quantum synchronization. He gave a talk on this and had discussion on many-body open systems with F. Essler. He was also involved in a discussion on supersolids lead by S. Stringari.

HOLGER FRAHM participated in the focus weeks on "Low dimensional systems". During his visit he has worked on possible realizations of non-Abelian anyons as low energy quasi-particle excitations in one-dimensional systems of interacting fermions. Part of this work is available on the arXiv by now. In this context he had discussions with A. Tsvelik and F. Essler on deformations of integrable spin chains with higher rank symmetries. In addition there has been a discussion with M. Rigol on the construction of corner transfer matrix eigenstates of the six-vertex model in the context of emerging structures in non-equilibrium dynamics.

VLADIMIR GRITSEV worked on a paper about a random matrix theory approach to many-body localization now available in preprint form as arXiv1807.05075. His work benefitted from discussions with T. Prosen and M. Serbyn, and a collaboration on a new project with Maksym and his group was initiated. He also collaborated with J. Schmiedmayer and his postdoc S. Ji on commensurate-incommensurate transition in coupled condensates.

FABIAN HEIDRICH-MEISNER had very helpful discussions with B. Bertini, M. Collura, J. De Nardis, F. Essler, M. Fagotti, A. Lamacraft, T. Prosen and J. Schmiedmayer on their research and my ongoing work on thermalization in one-dimensional models. These discussions as well as the support of ESI will be acknowledged in a forthcoming manuscript on "Thermalization in the 1d Holstein polaron problem".

MICHAEL KASTNER'S main scientific interactions during his stay at the ESI in Vienna were with A. Gambassi on time-dependent variational principles for long-range spin models, with J. Garrahan on nonequivalent ensembles of trajectories and with T. Gasenzer on the discrete truncated Wigner approximation for the numerical calculation of the time-evolution of observables in quantum spin models. The latter included working towards the completion of a paper (arXiv:1805.05221, submitted to the journal Quantum Science and Technology), in which the programme at the ESI is acknowledged.

ROBERT KONIK had valuable interactions with J. Schmiedmayer and his group at the Atominstitut at TU Wien. He learned of his ongoing work and discovered some useful target problems for future work. He had helpful discussions with I. Mazets on quenches in cold atomic gases and with A. Nahum on dynamically enlarged symmetries in 2D quantum systems and the possibility of seeing critical theories with these symmetries using the TSA+DMRG approach.

ESPERANZA LOPEZ collaborated with German Sierra and Manuel Campos on the application of tensor network techniques to quantum field theories. She also explored several aspects of quantum revivals in spin systems with Mari Carmen Banuls. This project had a big step forward thanks to the work done at the ESI.

ADITI MITRA visited the ESI for two weeks and had significant discussions with Luca Tagliacozzo, Mari Carmen-Banuls, Joerg Schmiedmayer, Markus Oberthaler. Her visit will likely lead to a publication with Luca Tagliacozzo on combining numerical and analytical studies in quantum quenches in an interacting 1d system.

ROEDRICH MOESSNER had exchanges with S. Diehl, B. Dora, F. Essler, P. Fendley, V. Gurarie, A. Laeuchli among others. He also learnt about some interesting recent developments he had been largely unaware of such as the experimental breakthroughs on Rydberg atoms, which were presented in a very good blackboard talk.

ADAM NAHUM regarded the quality of the talks extremely high and full of many new ideas, especially from those coming from the integrability community, that were new to him. He had useful and stimulating discussions with many people, including B Bertini, M Fagotti, R Konik, G Mussardo, A Laeuchli, H.G. Evertz, P. Calabrese, D. Bernard, B. Doyon, J.S. Caux, F. Essler, M. Oberthaler, F. Verstraete, V. Alba, E. Dellatorre, U. Schneider. He also discussed project ideas with R. Konik, and separately with B. Bertini and M. Fagotti that probably will end up on a longer timescale.

LORENZO PIROLI found his participation to the ESI programme extremely useful. During the stay, he mostly focused on carrying on with his work on the so-called generalized hydrodynamic approach to quantum integrable dynamics. In particular, he extensively discussed this with leading experts on this field, namely B. Bertini, M. Fagotti, B. Doyon and J. Dubail.

These interactions have already led to some results, now collected in the preprint B. Bertini, M. Fagotti, L. Piroli, and P. Calabrese, arXiv:1805.01884, which will appear in J. Phys. A. Furthermore, he initiated a collaboration with M. Kormos and B. Bertini, on interesting aspects of the generalized hydrodynamics in the sine-Gordon integrable quantum field theory. This is expected to lead to a publication within a couple of months. Finally, the ESI programme gave him the opportunity to chat about research topics which are not within his expertise. He had in particular discussed with Yuri D. van Nieuwkerk on interesting aspects of his most recent work.

TOMAZ PROSEN interacted most intensively with Vladimir Gritsev and Maksim Serbyn on the problem of characterizing quantum chaos across the many-body localization transition. In particular, they have been discussing the possibility of implementing the spectral form factor as an order parameter to detect the transition. Contrary to usual transition indicators, such as the ratio of consecutive level spacing, the spectral form factor contains the full information about dynamics on all time scales, so it would be of interest to analyse the behaviour of the so-called Thouless time-scale (where the random matrix behaviour sets in) on the disorder strength. These numerical experiments are now under investigation. He also continued his work on a minimal model of quantum many-body chaos, the kicked Ising model at the self-dual point, and analytically evaluated the dynamics of entanglement entropy at this self-dual model. The results of this work are now being prepared for publication.

MARCOS RIGOL was in Vienna between May 7 and May 12 where he had deep discussions with A. Tsvelik about nonlocal superconductivity mediated by Mott stripes (related to this preprint https://arxiv.org/abs/1804.00670). They will continue collaborate on this in the future. He also discussed with H. Frahm about eigenstates of boost operators, which is of great interest to the work done by M. Rigol on emergent eigenstate solution (the topic of his talk at ESI). He also interacted with M. Dalmonte.

JÖRG SCHMIEDMAYER worked intensively with F. Essler on various aspects of non-equilibrium physics of nearly integrable systems and how they can be implemented in the laboratory, and how they can be measured. Some of the results are written up in https://arxiv.org/abs/1806.02626. In addition he worked intensively with T. Gasenzer, J. Berges and S. Erne on universality far from equilibrium in quench cooling 1d systems, which resulted in https://arxiv.org/abs/1805. 12310. He also worked with S. Flörchinger on aspects of implementing string breaking in the sine-Gordon model, with G. Takacs on aspects of the sine Gordon model, and with M. Rigol and D. Weiss on aspects of the implementations of Newton's cradle in 1d systems. In addition he organised many lab visits to his 1d quantum experiments to give the theory a real-world connection.

DIRK SCHURICHT worked on a long-standing project with Robert Konik and Neil Robinson on the topological properties of Heisenberg spin ladders. In addition, he had intensive discussions with Marton Kormos on the overlap singularities present in the initial states appearing after quantum quenches in integrable systems possessing bound state excitations. Furthermore, he had very interesting and useful discussions with Bruno Bertini on quantum quenches, Benjamin Doyon on thermal transport in one-dimensional systems, and Juan Garrahan on the non-Markovian time evolution in open quantum systems. He also had in-depth discussions with Holger Frahm on integrable systems, and David Weiss and Jörg Schmiedmayer on general aspects of quantum quenches with a particular focus on the experimental aspects.

Maksym Serbyn's participation in "Quantum Paths" was very beneficial for his ongoing work, and for initiating new collaboration. In particular, the discussions with F. Verstraete, F. Essler, and K. Schoutens helped in finalizing the work on quantum scars. This work is available as a preprint arXiv:1806.10933; an acknowledgment of the ESI will be added to the published version. He also had discussions with V. Gritsev on the properties of the level statistics crossover between many-body localized and ergodic phases. This may potentially result in a future collaboration on the subject of the level statistics crossovers in ergodicity breaking transitions. In addition he had many discussions on the properties of form factors and level statistics with T. Prosen.

German Sierra had discussions with O. Castro Alvaredo and B. Doyon on the entanglement of excited states in Quantum Field Theory. The problem is to understand the relation between the general results they obtained and those known in Conformal Field Theory. This established a new collaboration. He also discussed with E. Lopez and M. Campos on the application of the tensor network MERA to the computation of the partition function of bosons in 1 dimension. This was an ongoing project that was greatly boosted during the stay at ESI. He also benefited from discussions with M.-C. Banuls and B. Paredes concerning her general construction of anyon theories.

Gabor Takacs discussed his recent work on correlation functions of the sine-Gordon theory in and out of equilibrium with J. Schmiedmayer and I. Mazets. Discussions with are continuing with the aim of establishing direct contact between theory and experiments. Feedback on his presentation were very helpful, especially some made by F. Essler. While at the ESI, he prepared the revised version of his paper Dynamical manifestation of the Gibbs paradox after a quantum quench with M. Collura and M. Kormos. The ESI acknowledged in the revised manuscript. He also discussed issues related to Josephson junction dynamics with A. Minguzzi, and started a collaboration on this subject.

Eric Vernier took the opportunity to interact with several participants, in particular with Bruno Bertini and Tomaz Prosen. Together they started discussing aspects of the chaotic vs integrable dynamics in free or interacting quantum spin chains. Since then they have kept on collaborating on these matters, and hopefully these results will reach a publishable form by the end of the year.

Andrey Zheludev had some very insightful discussions with Fabian Essler, Thierry Giamarchi and Alexey Tsvelik, basically on two significant subjects: the spin-nematic state in the frustrated square lattice Heisenberg model, as realized in the compound BaCdVO(PO4)2, and some non-universal features in the excitation spectrum of the strong-rung Heisenberg spin ladder material BPCB.

List of talks

Conference: Quantum Paths in Low Dimensions: Theory and Experiment, April 9 – 13, 2018

Ignacio Cirac	Tensor networks: fundamental theorems and applications
Frank Verstraete	Continuous variational matrix product states for quantum field theories
Jens Eisert	Quantum simulators probing the non-equilibrium

Markus Oberthaler	Spin-1 many-body system: Einstein Podolsky Rosen Correlations & Universal Time Dynamics
Dan Stamper-Kurn	Interacting bosonic atoms in triangular lattices with varying geometry
Jürgen Berges	Universality far from equilibrium and entanglement entropy
Andreas Läuchli	Quantum Criticality in iMPS & iPEPS Tensor Network Methods
Francesca Ferlaino	Observation of Roton Modes in an Erbium Dipolar quantum gas
Dimitry Abanin	Quantum many-body scars: a new mechanism of ergodicity breaking
Ulrich Schneider	Ultracold atoms in low-dimensional quasi-periodic potentials
Eugene Demler	Quench and Floquet dynamics in solid state systems and ultracold atoms
Bruno Bertini	Transport in Closed One-Dimensional Systems: Integrable Models and Universality at Low Temperatures
Adam Nahum	Emergent statistical mechanics of entanglement in random unitary circuits
Jean-Sebastien Caux	Quench, Hydro and Floquet dynamics in solvable many-body quantum systems
Hanns-Christoph Nägerl	Impurity dynamics in 1D for strong interactions: Bloch oscillations in the absence of a lattice
Rosario Fazio	Finite frequency criticality and time-crystals
Denis Bernard	Curiosities in monitoring quantum systems (in or out-of-equilibrium)
Lukasz Fidkowski	Fermionic symmetry protected phases via 2+1d bosonization
Robert Konik	Rare States and Anomalous Thermalization in the 1D and 2D Quantum Ising Model
Zoran Hadzibabic	Bose gases quenched to unitarity
Sandro Stringari	Propagation of sound in two-dimensional Bose gases
Tin-Lun Ho	Monopoles and Instantons in Cold Atoms
Jörg Schmiedmayer	Relaxation, (pre-) thermalization and revivals in (nearly) integrable systems: an experimental perspective

Week 2: Non-equilibrium dynamics, April 16 – 20, 2018

Roderich Moessner	Thermodynamics and order beyond equilibrium – from eigenstate thermalisation to time crystals
Juan Garrahan	Large deviations and "thermodynamics of trajectories" in open quantum systems
Sebastian Will	Quantum Control of Ultracold Dipolar Molecules
Jerome Dubail	Hydrodynamics of 1d bosons with delta repulsion in the Quantum Newton Cradle setup

Week 3: Non-equilibrium dynamics, April 23 – 27, 2018

Victor Gurarie	Quantum particles in a random potential in high dimensions
Stefan Floerchinger	Thermalization and fluid dynamics in high energy collisions
Paul Fendley	Preserving Quantum Coherence
Sebastian Diehl	Probing the topology of density matrices
Andrea Gambassi	Dynamical transitions, universality, and chaos in prethermal states

Week 4: Low dimensional systems, April 30 – May 4, 2018

Andrey Zheludev	Quantum particles in a random potential in high dimensions
Thierry Giamarchi	Double sine-Gordon transitions in quantum spin chains
Masaki Oshikawa	Polarization in quantum many-body systems
Tetsuo Deguchi	Quantum state of a dark solition
Martin Ganahl	New methods for continuous matrix product states

Week 5: Low dimensional systems, May 7 – 11, 2018

Gergeley Zarand	Semi-semiclassical theory of one-dimensional non-equilibrium systems
Marcos Rigol	Emergent eigenstate solution to quantum dynamics far from equilibrium
David Weiss	Dynamics of 1D gases, integrable and otherwise

Alexei Tsvelik　　Fractionalized Fermi liquid in a Condo-Heisenberg model

Week 6: Tensor networks & entanglement, May 14 – 18, 2018

Mari-Carmen Banuls	Using Matrix Product Operators to explore MBL
Anatoli Polkovnikov	Cluster Truncated Wigner Approximation for strongly correlated quantum systems
Olalla Castro Alvaredo	Entanglement Content of Particle Excitations in Quantum Field Theory
Belén Paredes	Boson-Lattice construction for anyon models
Frank Pollmann	Quantum Thermalization Dynamics

Week 7: Tensor networks & entanglement, May 22 – 25, 2018

Tomaz Prosen	A Minimal Solvable Model of Many-Body Quantum Chaos
Aditi Mitra	Transport signatures of transient superfluids
Andreas Klümper	Universality and quantum criticality of the one-dimensional spinor Bose gas
Joe Bhaseen	Stochastic Approach to Non-Equilibrium Quantum Spin Systems

Week 8: Mini-Conference on "Non-ergodicity & integrability", May 28 – June 1, 2018

Kareljan Schoutens	Many-body strategies for multi-qubit gates
Gabor Takacs	Correlation functions of the quantum sine-Gordon model in and out of equilibrium
Austen Lamacraft	Operator Moments of Noisy Coupled Qubits and the Fredrickson-Andersen Model
Maksym Serbyn	Probing ergodicity breaking with matrix elements
Neil Robinson	Nonthermal states in theories with confinement
Nicolo Defenu	Quantum anomaly and scaling dynamics in the 2D Fermi gas
Anna Minguzzi	Damping of Josephson oscillations in strongly correlated one-dimensional atomic gases
Victor Galitski	Quantum Lyapunov Exponents
Jacopo de Nardis	Large scale dynamics of an interacting 1d Bose gas: hydrodynamics, particle-hole excitations and non- equilibrium steady states
Mario Collura	Order-parameter statistics out-of-equilibrium in many-body quantum systems
Alessio Chiocchetta	Fluctuation-induced quantum Zeno effect
Stefan Groha	Full counting statistics in the transverse field Ising model in and out of equilibrium
Maurizio Fagotti	Time evolution of the bipartite entanglement in interacting integrable systems
Andrea de Luca	Solution of a minimal model for many-body quantum chaos
Laurens Vanderstraeten	Quasiparticle Excitations with Tensor Network States
Eric Vernier	Out-equilibrium dynamics of quantum integrable models: What can we compute exactly?
Elena Tartaglia	Entanglement and diagonal entropies after a quench with no pair structure
Alessio Lerose	Quantum many-body Kapitza phases of periodically driven spin systems
Luca Lepori	Long-range topological insulators and weakened bulk-boundary correspondence
Vladimir Gritsev	Integrability for dynamics, topology and disorder

Publications and preprints contributed

A substantial number of publications acknowledging the programme is in preparation at the time of writing of this report. The following works have already appeared in preprint form or have been published:

V. Alba, B. Bertini, M. Fagotti, *Entanglement evolution and generalised hydrodynamics: interacting integrable systems*, arXiv:1903.00467 [cond-mat.stat-mech].

V. Alba, S.N. Santalla, P. Ruggiero, J. Rodriguez-Laguna, P. Calabrese, G. Sierra, *Unusual area-law violation in random inhomogeneous systems*, arXiv:1807.04179 [cond-mat.stat-el].

A. Bastianello, P. Calabrese, *Entanglement evolution and generalised hydrodynamics: noninteracting systems*, arXiv:1807.10176 [cond-mat.stat-mech].

B. Bertini, M. Fagotti, L. Piroli, P. Calabrese, *Entanglement evolution and generalised hydrodynamics: noninteracting systems*, arXiv:1805.01884 [cond-mat.stat-mech].

B. Bertini, P. Kos, T. Prosen, *Entanglement spreading in a minimal model of maximal many-body quantum chaos*, arXiv:1812.05090 [cond-mat.stat-mech].

B. Bertini, L. Piroli, M. Kormos, *Transport in the sine-Gordon field theory: from generalized hydrodynamics to semiclassics*, arXiv:1904.02696 [cond-mat.stat-mech].

D. Borcherding, H. Frahm, *Condensation of non-Abelian $SU(3)_{N_f}$ anyons in a one-dimensional fermion model*, arXiv:1808.05808 [cond-mat.stat-el].

W. Buijsman, V. Cheianov, V. Gritsev, *Random Matrix Ensemble for the Level Statistics of Many-Body Localization*, arXiv:1807.05075 [cond-mat.dis-nn].

O. A. Castro-Alvaredo, C. De Fazio, B.Doyon, I. M. Szécsényi, *Entanglement Content of Quasi-Particle Excitations*, arXiv:1805.04948 [cond-mat.stat-mech].

O. A. Castro-Alvaredo, C. De Fazio, B.Doyon, I. M. Szécsényi, *Entanglement Content of Quantum Particle Excitations I. Free Field Theory*, arXiv:1806.03247 [hep-th].

S. Czischek, M. Gärttner, M. Oberthaler, M. Kastner, T. Gasenzer, *Quenches near criticality of the quantum Ising chain—power and limitations of the discrete truncated Wigner approximation*, arXiv:1805.05221 [quant-ph].

S. Erne, R. Buecker, T. Gasenzer, J. Berges, J. Schmiedmayer, *Observation of universal dynamics in an isolated one-dimensional Bose gas far from equilibrium*, arXiv:1805.12310 [cond-mat.quant-gas].

D. A. Rowlands, A. Lamacraft, *Noisy Coupled Qubits: Operator Spreading and the Fredrickson-Andersen Model*, arXiv:1806.01723 [cond-mat.stat-mech].

V. Gurarie, *Dynamical quantum phase transitions in the random field Ising model*, arXiv:1806.08876 [cond-mat.stat-mech].

S. Groha, F.H.L. Essler, P. Calabrese, *Full counting statistics in the transverse field Ising chain*, SciPost Phys. 4, 043 (2018). https://scipost.org/SciPostPhys.4.6.043.,

A. J. A. James, R. M. Konik, N. Robinson, *Nonthermal states arising from confinement in one and two dimensions*, arXiv:1804.09990 [cond-mat.stat-mech].

M. Mestyàn, B. Bertini, L. Piroli P. Calabrese, *Spin-charge separation effects in the low-temperature transport of one-dimensional Fermi gases*, APS Journals, Physical Review B, https://journals.aps.org/prb/abstract/10.1103/PhysRevB.99.014305, arXiv:1810.01089 [cond-mat.quant-gas].

Y.D. van Nieuwkerk, J. Schmiedmayer, F.H.L. Essler, *Projective phase measurements in one-dimensional Bose gases*, arXiv:1806.02626 [cond-mat.quant-gas].

C. Cheng, R. Mondaini, M. Rigol, *Singlet pairing and superconductivity in t-J ladders with Mott insulating stripes*, arXiv:1804.00670 [cond-mat.str-el].

C. J. Turner, A. A. Michailidis, D. A. Abanin, M. Serbyn, Z. Papić, *Quantum scarred eigenstates in a Rydberg atom chain: entanglement, breakdown of thermalization, and stability to perturbations*, arXiv:1806.10933 [cond-mat.quant-gas].

Invited scientists

Dmitry A. Abanin, Vincenco Alba, Mari-Carmen Banuls, Alvise Bastianello, Jürgen Berges, Bruno Bertini, Denis Bernard, Joe Miraculous Bhaseen, Pasquale Calabrese, Manuel Campos Yuste, Andrea

Cappelli, Olalla Castro-Alvaredo, Jean Sebastian Caux, Alessio Chioccetta, Ignacio Cirac, Mario Collura, Emanuele Dalla Torre, Marcello Dalmonte, Daniele De Bernardis, Andrea De Luca, Nicoló Defenu, Jacopo De Nardis, Tatsuo Deguchi, Eugene Demler, Sebastian Diehl, Balazs Dora, Benjamin Doyon, Jerome Dubail, Jens Eisert, Fabian Essler, Hans Gerd Evertz, Mauricio Fagotti, Rosario Fazio, Francesca Ferlaino, Paul Fendley, Lukaszi Fidkowski, Stefan Flörchinger, Holger Frahm, Victor Galitsky, Andrea Gambassi, Martin Ganahl, Juan P. Garrahan, Thomas Gasenzer, Thierry Giamarchi, Anna Goremykina, Vladimir Gritsev, Stefan Groha, Daniel Grumiller, Victor Gurarie, Zoran Hadzibabic, Philipp Haslinger, Fabian Heidrich-Meisner, Markus Heyl, Jason Ho Tin-Lun, Marcus Huber, Michael Kastner, Andreas Klümper, Robert Konik, Marton Kormos, Ilya Kull, Austen Lamacraft, Andreas Läuchli, Mikhail Lemeshko, Luca Lepori, Alessio Lerose, Xiao Li, Qi Liang, Esperanza López, Izabella Lovas, Mira Maiwöger, Igor Mazets, Anna Minguzzi, Aditi Mitra, Roderich Moessner, Giuseppe Mussardo, Bruno Nachtergaele, Adam Nahum, Hanns C. Nägerl, Markus Oberthaler, Masaki Oshikawa, Arijeet Pal, Belén Paredes, Lorenzo Piroli, Didier Poilblanc, Anatoli Polkovnikov, Frank Pollmann, Tomaz Prosen, Peng Rao, Dennis Rätzel, Marcos Rigol, Neil Robinson, Joao Sabino, German Sierra, Jörg Schmiedmayer, Ulrich Schneider, Kareljan Schoutens, Dirk Schuricht, Robert Seiringer, Maksym Serbyn Alessandro Silva, Dan Stamper-Kurn, Hans Peter Stimming, Sandro Stringari, Luca Tagliacozzo, Mohammadamin Tajik, Gabor Takacs, Elena Tartaglia, Andrea Trombettoni, Alexei Tsvelik, Benoit Tuybens, Maarten Van Damme, Laurens Vanderstraeten, Bram Vanhecke, Yuri van Nieuwkerk, Jonas Verhellen, Eric Vernier, Frank Verstraete, David Weiss, Sebastian Will, Ru Gway Wu, Gergely Zaránd, Johannes Zeiher, Andrey Zheludev, Aleksandra Ziolkowska.

Numerical Analysis of Complex PDE Models in the Sciences

Organizers: Annalisa Buffa (EPFL Lausanne), Thomas Y. Hou (Caltech), J. Markus Melenk (TU Vienna), Ilaria Perugia (U Vienna), Christoph Schwab (ETH Zurich)

Dates: June 11 – August 17, 2018

Budget: ESI € 58 320,
other sources:
Austrian Science Fund (FWF): € 2 817 through the Project F 65, € 1 875 through the Project P 30148, and € 912 through the Project P 29197,
ETH Zurich and Swiss National Science Foundation: € 6 174,
Caltech: € 2 634,
Vienna University of Technology: € 250.

Report on the programme

The programme gathered numerical analysis experts who are active in the mathematics of novel, "non standard" discretizations for complex partial differential equations (PDEs) featuring multiple fields, multiple scales, and stochastic effects. The aim was a synthesis of advanced and innovative discretizations, such as discontinuous Galerkin methods, isogeometric analysis, virtual element methods, and reduced basis methods, on the one side, with compressive discretizations inspired by computational harmonic analysis (wavelets, directional representation systems), completely new discretization methods based on recent developments in signal processing (compressive sensing and other randomization methods), and novel compression techniques from numerical linear algebra (H-matrix and tensor structured methods), on the other side.

Activities

During the programme, three workshop and a lecture course took place:

- Workshop 1: Interplay of tensor structured formats with advanced PDE discretizations; session on Signal processing techniques and directionally adapted discretizations, June 11 – 15, 2018, (organizers: Philipp Grohs and Christoph Schwab);

- Workshop 2: Interplay of multiscale data assimilation and data science with advanced PDE discretizations, June 25 – 29, 2018 (organizers: Thomas Hou and Markus Melenk);

- Workshop 3: Interplay of geometric processing, modelling, and adaptivity in Galerkin methods, July 16 – 20, 2018 (organizers: Annalisa Buffa and Ilaria Perugia);

- Lecture course: Francis Filbet (University of Toulouse III), "Introduction to Kinetic Theory: The Boltzmann Equation" July 30 – August 3, 2018.

Specific information on the programme

The overall response for the general programme has been very positive. The programme has able attracted well-known, key researchers at the forefront of the fields of computational methods for data assimilation, deep learing, multiscale problems, inverse problems, and novel discretization techniques for PDEs. Although three different themes in three workshops were covered, they complemented each other very well. A number of the participants requested to participate to two or more workshops and to stay in the week in between. Researchers from the different areas really interacted, which was one of primary goals when designing the thematic program.

WS1 broke new ground and spawned several new research projects in the use of deep learning techniques for the numerical approximation of PDE solutions; this research direction has emerged in the past year, and was not originally foreseen in the original proposal. The idea of bringing people who work on data assimilation and data science with people who work on numerical PDEs has been a successful one. More and more people start to use data in their research in an essential way. This aspect was highlighted in WS2 and the general program to some extent. Several lectures in WS2, T. Hou's in particular, were key to bridging the Data-Science/PDE numerics gap successfully. New ideas on the integration of geometric processing and PDE solvers, and on recent PDE structure-aware numerical methods, which are establishing new ground in adaptivity, have been discussed and further elaborated in WS3.

The overall quality of the speakers in the three workshops and in the lecture course was very high. During the workshops, there has been a lot of interaction both during the talks and during the breaks. In the weeks in between, many discussions took place at the institute and many collaborations among the participants having been advanced and new project having been initiated. The talks were well-attended by people from Vienna working in computational PDEs. The excellent course by Francis Filbet on the Boltzmann equations was attended by quite a number of PhD-students.

Outcomes and achievements

During the programme, the participants started new projects and collaborations, and had the opportunity to continue to work on ongoing projects. We include here a few samples. A de-

tailed list of scientific talks is provided in the next section.

ASSYR ABDULLE and GILLES VILMART were able to work together and make substantial progress on an ongoing project.

ANDREA ASPRI discussed with OTMAR SCHERZER an ongoing project about modified versions of iterative methods for nonlinear inverse problems with data driven priors.

SÖREN BARTELS and RICARDO NOCHETTO discussed an ongoing project and identified an idea for a new project. Both projects are related to the keywords numerical analysis, nonlinear partial differential equations, convergence analysis, harmonic maps, liquid crystals.

RICARDO NOCHETTO had also the opportunity to interact with PETER BINEV on hp adaptive approximation, with J. MARKUS MELENK on optimal FEMs for fractional diffusion, and with ILARIA PERUGIA on a posteriori error estimation for the Helmholtz equation.

LOURENÇO BEIRÃO DA VEIGA's research perspective benefitted in general terms by the scientific conversations with the participants to Workshop 3.

FLEURIANNE BERTRAND discussed ongoing projects especially with JOACHIM SCHÖBERL and DANIELE BOFFI; moreover she was able to start a new project with DANIELE BOFFI on a new mixed formulation for elasticity.

In addition to that, DANIELE BOFFI had the opportunity to interact with RICARDO NOCHETTO, DIRK PRAETORIUS, and GUIDO KANSCHAT on the latest news on a posteriori estimates and convergence of adaptive schemes.

GUIDO KANSCHAT also discussed and drafted a publication on robust inf-sup stability with JOACHIM SCHÖBERL; he had scientific discussions with BERNARDO COCKBURN on HDG software, and started a collaboration on tensor product cochains with FRANCESCA BONIZZONI. Moreover, he discussed tensor formats with MARKUS BACHMAYR and VLADIMIR KAZEEV, that strongly impacted his further research plans.

In addition to the aforementioned scientific discussion with GUIDO KANSCHAT, VLADIMIR KAZEEV discussed ongoing and new projects on the numerical solution of PDEs using adaptive low-rank tensor approximations with CHRISTOPH SCHWAB, MARKUS BACHMAYR, and MAKSIM RAKHUBA, and had broad scientific discussions of possible developments with MARIO BEBENDORF, SERGEY DOLGOV, BJORN ENGQUIST, REINHOLD SCHNEIDER, and the aforementioned GUIDO KANSCHAT.

STEFFEN BÖRM's research about compression of high-frequency Helmholtz problems has benefited from his stay at the ESI; he had fruitful discussions with LARS GRASEDYCK, J. MARKUS MELENK, and JOACHIM SCHÖBERL. A conversation with MARIO BEBENDORF may lead to closer cooperation in the future.

SUSANNE BRENNER worked on an ongoing project with JOSCHA GEDICKE on optimal con-

trol problems, and started a new cooperation with DANIEL PETERSEIM on multiscale problems.

DANIEL PETERSEIM continued also an ongoing collaboration with MICHAEL FEISCHL on sparse compressibility of inverse random partial differential operators and corresponding multiresolution compression schemes. An additional research line on numerical analysis of numerical stochastic homogenization (in particular, a priori variance estimation) resulted in a new collaboration with JULIAN FISCHER Daniel Peterseim had also fruitful discussion with other participants, in particular with GUANGLIAN LI on localization techniques for convection dominated diffusion problems. Further discussions with ILARIA PERUGIA on wave propagation in heterogeneous media, with GREGOR GANTNER on adaptive approximation of inverse partial differential operators, and with VIET-HA HOANG and BARBARA VERFÜRTH on space-time multiscale methods may lead to new projects in the next months.

BARBARA VERFÜRTH had also fruitful scientific discussions with JOACHIM SCHÖBERL, J. MARKUS MELENK, RALF HIPTMAIR, GILLES VILMART, and LISE-MARIE IMBERT-GÉRARD.

ANDREA BRESSAN started a collaboration with CHRISTOPH SCHWAB on the convergence of the IGA method in the presence of singularities.

FRANCO BREZZI interacted with many participants, thus getting several good hints concerning the singularities of solutions of div-curl systems. He expects these contributions to benefit his work on Virtual Element Methods, and their application in Scientific Computing.

ERIK BURMAN discussed recent ongoing projects on inverse problems, fictitious domain methods and boundary element methods with PETER MONK and FRANCISCO-JAVIER SAYAS.

ZHIMING CHEN had the chance to discuss with RICARDO NOCHETTO about the adaptive finite element method for solving elliptic equations with discontinuous coefficients (with the interface of the discontinuity possibly curved and/or having singularities). This may lead to new collaboration on a project which is connected to the recent work of Andrea Bonito and RICARDO NOCHETTO on adaptive DG methods on hanging node meshes.

BERNARDO COCKBURN had fruitful scientific discussions with RICARDO NOCHETTO, JOACHIM SCHÖBERL, IAIN SMEARS, LOURENÇO BEIRÃO DA VEIGA, and GUIDO KANSCHAT, and started a new collaboration with FRANCO BREZZI.

WOLFGANG DAHMEN's work benefitted from discussions with MARKUS BACHMAYR, LESZEK DEMKOWICZ, GUIDO KANSCHAT, HELMUT HARBRECHT, and REINHOLD SCHNEIDER. This may lead to a possible new project with MARKUS BACHMAYR, HELMUT HARBRECHT and REINHOLD SCHNEIDER about deep neural networks, kinetic equations, and nonlocal operators. Moreover, WOLFGANG DAHMEN carried on fruitful scientific discussions with HELMUT HARBRECHT about a joint project on efficient discretization techniques for the fractional Laplacian. A new project with ANTONY NOUY was also started.

In addition to the aforementioned project, ANTONY NOUY started new scientific projects with REINHOLD SCHNEIDER and MARKUS BACHMAYR.

SERGEY DOLGOV had the opportunity to discuss ongoing projects with VLADIMIR KAZEEV, REINHOLD SCHNEIDER, BORIS KHOROMSKIJ, and DANIEL KRESSNER on low-rank tensor approximations to matrix functions, and optimisation of tensor networks.

ALEXANDRE ERN made progress in the final writing of his Finite element book (co-authored with J. L. Guermond, not participating in the Thematic Programme). Fruitful scientific discussions about ongoing projects were carried on with JOSCHA GEDICKE (on a posteriori error estimation), RICARDO NOCHETTO (on nonconforming methods), ERIK BURMAN (on unfitted finite element methods), and IAIN SMEARS (on space-time methods for the heat equation).

JOHN EVANS' research efforts in geometric modeling and mesh generation were aided by his attendance of the Thematic Programme (were he also gave a talk on this topic). In addition to that, also his research on structure-preserving discretizations for incompressible flow were benefitted by his stay in Vienna. In this later direction, he discussed future collaborations with MICHAEL NEILAN, who is also working in structure-preserving discretizations for incompressible flow.

FRANCIS FILBET, who gave a lecture course in the framework of the Thematic Programme, had the opportunity to discuss his work with many students (PhD and Master) and also Postdocs who attended his lectures and who work on the same topic. He also could scientifically interact profitably with J. MARKUS MELENK, ILARIA PERUGIA, and CHRISTOPH SCHWAB.

GREGOR GANTNER was able to talk with ANNALISA BUFFA, CARLOTTA GIANNELLI, and RAFAEL VÁZQUEZ about an ongoing project. Moreover, he had the opportunity to discuss with PETER BINEV about one of his papers.

RALF HIPTMAIR started a joint research with LISE-MARIE IMBERT-GÉRARD concerning (i) a convergence proof for a discontinuous Galerkin method based on generalized plane wave that IMBERT-GÉRARD developed, and (ii) the possibility of precomputing oscillatory integrals as they occur in an implementation of that method. Moreover, he discussed with ANDREA MOIOLA concerning a particular approximation problem that comes up in the context of the so-called FLAME method, proposed by Igor Tsukerman.

CLEMENS HOFREITHER's attendance of Workshop 1 of the Thematic Programme was highly beneficial in order to let him gain insight on the state of the art of fast tensor approximation methods for partial differential equations. He had discussions with MARKUS BACHMAYR on which methods would be most suitable for his applications, in particular the AMEn method and methods based on soft thresholding. Furthermore, he had fruitful discussions with GUIDO KANSCHAT on implementation issues. CHRISTOPH SCHWAB's comments relating to Quantized Tensor Train (QTT) approximation were highly useful in guiding his future research direction.

TOM HOU, together a postdoc and a student of his, have learned a lot from the second workshop, and had some very stimulating discussions with some of the speakers and participants. Some of these discussions led to interesting new ideas that they started to pursue after they returned to Caltech.

BERT JUETTLER worked with ANNALISA BUFFA, ULRICH LANGER, and GIANCARLO SAN-GALLI on isogeometric analysis.

In addition to that, GIANCARLO SANGALLI discussed with RICARDO NOCHETTO topics connected with adaptivity and anisotropy, with ANNALISA BUFFA about many ongoing projects on isogeometric analysis, and with THOMAS TAKACS about isogeometric spaces on multipatch geometries.

Workshop 2 gave BARBARA KALTENBACHER the opportunity to continue discussions with OTMAR SCHERZER and members of his group about the solution of an inverse problem for the wave equation by means of optimal control techniques. Moreover, she used the opportunity to get from SEBASTIAN REICH valuable information and material on parameter identification in stochastic differential equations.

DANIEL KRESSNER discussed with several people working on tensors, in particular with SERGEY DOLGOV; the two are now planning at finalizing a paper close to the topic of Workshop 1 (low-rank tensor). DANIEL KRESSNER also had interesting discussions with FRANCESCA BONIZZONI; this may lead to start a collaboration on reduced basis methods.

During her attendance to Workshop 3, DONATELLA MARINI had fruitful conversations with many participants on topics related to Galerkin methods, adaptivity, Finite Elements and Virtual Elements Methods.

MARKUS MELENK had very productive interactions with PETER BINEV, RICARDO NOCHETTO, RALF HIPTMAIR, STEFAN SAUTER, CHRISTOPH SCHWAB, BARBARA VERFÜRTH, and joint work with CHRISTOPH SCHWAB and STEFAN SAUTER will be published shortly.

During the Thematic Programme, ANDREA MOIOLA started new projects with ILARIA PERUGIA and CHRISTOPH SCHWAB on discontinuous Galerkin methods, and with LISE-MARIE IMBERT-GÉRARD on Trefftz methods. He also profited from learning from talks and informal discussions about several topics related to space-time Galerkin methods, multiscale problems, adaptivity, computational electromagnetics, and geometrical modelling.

In addition to the aforementioned projects with ANDREA MOIOLA and CHRISTOPH SCHWAB, and with RICARDO NOCHETTO, ILARIA PERUGIA worked on a new project with SILVIA BERTOLUZZA on negative norm stabilization of discontinuous Galerkin methods, and continued a project with FRANCESCA BONIZZONI, FABIO NOBILE, and DAVIDE PRADOVERA on Padé approximation of frequency-response problems.

SERGEI PEREVERZYEV collaborated with ANDREW STUART on the application of graph Laplacian in semi-supervised learning. The two participants also discussed about a possible project on the use of machine learning for diabetes technology.

During Workshop 2, GIANLUIGI ROZZA worked on ongoing projects with ILARIA PERUGIA, FRANCESCA BONIZZONI, and MARIO OHLBERGER.

STEFAN SAUTER had the opportunity to continue his scientific collaborations with J. MARKUS MELENK (on numerics for Maxwell equations), and with JOSCHA GEDICKE (on non-symmetric eigenvalue problems).

CHRISTOPH SCHWAB worked on ongoing projects, and had the opportunity of start new collaborations, with DENNIS ELBRAECHTER, PHILIPP GROHS, J. MARKUS MELENK, ANDREW STUART, ANDREA MOIOLA, ILARIA PERUGIA, and ANDREA BRESSAN. The Thematic Programme positively impacted his research on deep learning approximation rate bounds in acoustic scattering, Fractional Diffusion, space time discretization of linear wave equations in polyhedra, spacetime dG for Wave Equations on polygons, and hp-IsoGeometric FEM.

Through his participation in the Thematic Programme, ROB STEVENSON gained new valuable ideas for improved space-time variational formulations of parabolic PDEs. He benefitted from scientific presentations, as well as from discussions on this topic with CHRISTOPH SCHWAB, IAIN SMEARS, ULRICH LANGER, and OLAF STEINBACH.

LI-YENG SUNG was led by the talks of Workshop 2 to expand his research into new areas, in particular into starting a collaboration with DANIEL PETERSEIM on multiscale problems. In addition to that, he worked on an ongoing project with JOSCHA GEDICKE on elliptic optimal control problems.

List of talks

Workshop 1: Interplay of tensor structured formats with advanced PDE discretizations; session on Signal processing techniques and directionally adapted discretizations, June 11 – 15, 2018

Markus Bachmayr	Stability of Low-Rank Tensor Representations and Structured Multilevel Preconditioning for Elliptic PDEs (Part I)
Mario Bebendorf	Degenerate approximation of Green's function in the presence ofhigh-contrast coefficients
Steffen Börm	Hybrid compression of boundary element matrices for high-frequency Helmholtz problems
Wolfgang Dahmen	Data and Reduced Models
Leszek Demkowicz	Current Research Results on the DPG Method for Wave Propagation Problems
Sergey Dolgov	Solving large ODEs with conservation laws by low rank decompositions
Dennis Elbrächter	Approximation of high dimensional tensor products using deep ReLU networks
Michael Feischl	H-Matrices and Multi-index Monte Carlo
Philipp Grohs	Solving linear Kolmogorof equations by means of deep learning
Helmut Harbrecht	Second moment analysis for boundary value problems with random input parameters
Clemens Hofreither	Applications of Low-Rank Tensor Methods in Isogeometric Analysis
Guido Kanschat	Tensor based inversion for overlapping Schwarz smoothers
Vladimir Kazeev	Stability of Low-Rank Tensor Representations and Structured Multilevel Preconditioning for Elliptic PDEs (Part II)
Boris Khoromskij	Tensor numerical methods in computational quantum chemistry
Melvin Leok	Variational discretizations of gauge field theories using group-equivariant interpolation spaces
Lek-Heng Lim	Tensor network ranks
Anthony Nouy	Adaptive sampling for learning tree tensor networks
Philipp Petersen	Neural Networks and Partial Differential Equations: Challenges and Opportunities
Maksim Rakhuba	Tensor methods for high-dimensional eigenvalue problems

Holger Rauhut	Multilevel compressive sensing methods for parametric PDEs
Reinhold Schneider	Hierarchical Tensor Representation and Variational Monte Carlo
Thomas Strohmer	Uncertainty mitigation and inverse problems
Jakob Zech	Stochastic collocation and deep ReLU networks for UQ

Workshop 2: Interplay of multiscale data assimilation and data science with advanced PDE discretizations, June 25 – 29, 2018

Assyr Abdulle	Bayesian multiscale inverse problems and probabilistic numerical methods
Michal Branicki	Accuracy of a class of nonlinear filters for dissipative PDEs in the presence of model error
Zhiming Chen	The Reverse Time Migration Method for Inverse Scattering Problems
Eric Chung	Generalized multiscale finite element methods and nonlocal multi-continua upscaling for heterogeneous and fracture media
Yalchin Efendiev	Data Integration in Multiscale Simulations
Bjorn Engquist	Sampling and low rank compression of multiscale functions and operators
Dimitris Giannakis	Data-driven approaches for spectral decomposition of ergodic dynamical systems
Viet-Ha Hoang	Bayesian inverse homogenization
Thomas Hou	Sparse Operator Compression for Higher Order Elliptic PDEs and Graph Laplacians with Rough Coefficients
Lise-Marie Imbert-Gérard	Wave propagation in inhomogeneous media: Beyond the Helmholtz equation
Barbara Kaltenbacher	Adaptive discretization of inverse problems based on functional error estimators
Andrea Moiola	Scattering by fractal screens: functional analysis and computation
Peter Monk	Optimal design of thin film solar cells
Mario Ohlberger	Localized Model Reduction for PDE-constrained Parameter Optimization
Sergei Pereverzyev	Application of graph Laplacian in semi-supervised learning
Daniel Peterseim	Quasi-local numerical stochastic homogenization
Sebastian Reich	Data assimilation: Coupling of probability measures
Gianluigi Rozza	Reduced Order Methods: state of the art and perspectives with a special focus on Computational Fluid Dynamics
Stefan Sauter	Estimating the effect of data simplification for elliptic PDEs
Otmar Scherzer	On a multi-level algorithms for solving the inverse boundary value problem for the Helmholtz equation
Claudia Schillings	Well-posedness and convergence analysis of the ensemble Kalman inversion
Joachim Schöberl	Hybrid mixed methods for the Helmholtz equation
Zuoqiang Shi	PDE-based models in learning manifold
Benjamin Stamm	An embedded corrector problem for stochastic homogenization
Andrew Stuart	Large Graph Limits of Learning Algorithms
Barbara Verfürth	Numerical multiscale methods for Maxwell's equations in complex media
Gilles Vilmart	Uniformly accurate numerical schemes for highly oscillatory evolution problems
Jonathan Weare	Stratification for Markov Chain Monte Carlo Simulation

Workshop 3: Interplay of geometric processing, modelling, and adaptivity in Galerkin methods, July 16 – 20, 2018

Sören Bartels	Approximating gradient flow evolutions of self-avoiding inextensible curves and elastic knots
Lourenço Beirão da Veiga	The Stokes complex for Virtual Elements
Silvia Bertoluzza	Stabilizing DG methods on polygonal meshes via computable dual norms
Peter Binev	Near-Best Adaptive Approximation on Conforming Partitions
Daniele Boffi	Adaptive finite element method for the Maxwell eigenvalue problem
Andrea Bressan	Best approximation space on uniform partitions
Franco Brezzi	Virtual Element approximation of Magnetostatic problems via Vector Potential Formulation
Erik Burman	Integrating geometric data in the computational solution of PDE using cutFEM
Fehmi Cirak	Isogeometric analysis with manifold-based basis functions

Bernardo Cockburn	An introduction to the theory of M-decompositions
Alexandre Ern	Edge finite element approximation of Maxwell's equations in heterogeneous domains
John Evans	Mesh Generation, Parameterization, and Optimization for High-Order Finite Element and Isogeometric Analysis
Carlotta Giannelli	Refinement and coarsening strategies for adaptive methods with hierarchical splines
Jay Gopalakrishnan	Discretization errors in the FEAST algorithm for eigenvalues
Ralf Hiptmair	Approximating Shape Gradients
Bert Juettler	Accurate Numerical Quadrature on Trimmed Elements in Isogeometric Analysis
Ulrich Langer	Adaptive Space-Time Isogeometric Analysis
Donatella Marini	Lowest order Virtual Element approximation of magnetostatic problems
Pedro Morin	A new perspective on adaptive hierarchical B-splines
Michael Neilan	Exact smoothed piecewise polynomial sequences on Alfeld splits
Ricardo Nochetto	Structure preserving FEM for the Q-model of uniaxial nematic liquid crystals
Dirk Praetorius	Axioms of adaptivity revisited: Optimal adaptive IGAFEM
Giancarlo Sangalli	Computational efficiency in isogeometric analysis
Andreas Schröder	Error estimates for primal-hybrid and dual-mixed hp-finite element methods
Iain Smears	Time-parallel iterative solvers for parabolic evolution equations: an inf-sup theoretic approach
Olaf Steinbach	Coercive space-time finite element methods
Rob Stevenson	Optimal preconditioners of linear complexity for problems of negative order discretized on locally refined meshes
Thomas Takacs	C^1-smooth isogeometric spaces on multi-patch domains
Rafael Vázquez	Dual complex for structure preserving isogeometric methods

Lecture Course by Francis Filbet: Introduction to Kinetic Theory: The Boltzmann Equation, July 30 – August 3, 2018

The main topic of these lectures was the Boltzmann equation for rarefied gas dynamics. After a short introduction of the physical background, some basic tools to study the existence of solution for the homogeneous Boltzmann equation were reviewed. Then, some numerical approximation based on spectral methods were presented to the participants, as well as a rigorous convergence study.

Publications and preprints contributed

F. Bonizzoni, F. Nobile, I. Perugia, D. Pradovera, *Fast Least-Squares Padé approximation of problems with normal operators and meromorphic structure*, arXiv:1808.03112 [math.NA].

M. Feischl, D. Peterseim, *Sparse Compression of Expected Solution Operators*, arXiv:1807.01741 [math. NA].

P. Kürschner, S. Dolgov, K. D. Harris, P. Benner, *Greedy low-rank algorithm for spatial connectome regression*, arXiv:1808.05510 [math.NA].

J. M. Melenk, S. A. Sauter, C. Torres, *Wave number-Explicit Analysis for Galerkin Discretizations of Lossy Helmholtz Problems*, arXiv:1904.00207 [math.NA].

D. Peterseim, B. Verfürth, *Computational high frequency scattering from high contrast heterogeneous media*, arXiv:1902.09935 [math.NA].

M. Feischl, Ch. Schwab, *Exponential convergence in H 1 of hp-FEM for Gevrey regularity with isotropic singularities*, https://www.sam.math.ethz.ch/sam_reports/reports_final/reports2018/2018-29.pdf.

Invited scientists

Assyr Abdulle, Andrea Aspri, Markus Bachmayr, Sören Bartels, Mario Bebendorf, Lourenco Beirao da Veiga, Maximilian Bernkopf, Silvia Bertoluzza, Fleurianne Bertrand, Peter Binev, Steffen Börm, Daniele Boffi, Michal Branicki, Susanne Brenner, Andrea Bressan, Franco Brezzi, Francesca Bonizzoni, Annalisa Buffa, Erik Burman, Carsten Carstensen, Zhiming Chen, Eric Chung, Fehmi Cirak, Bernardo Cockburn, Scott Congreve, Wolfgang Dahmen, Leczek Demkowicz, Sergej Dolgov, Guozhi Dong, Yalchin Efendiev, Bjorn Engquist, Dennis Elbraechter, Alexandre Ern, John Evans, Markus Faustmann, Michael Feischl, Francis Filbet, Gregor Gantner, Joscha Gedicke, Dimitris Giannakis, Carlotta Giannelli, Jay Gopalakrishnan, Lars Grasedyck, Philipp Grohs, Helmut Harbrecht, Ralf Hiptmair, Viet-Ha Hoang, Clemens Hofreither, Tom Hou, De Huang, Lise-Marie Imbert-Gerard, Bert Juettler, Jeffery Ka-Chun Lam, Barbara Kaltenbacher, Guido Kanschat, Bernard Kapidani, Vladimir Kazeev, Boris Khoromskij, Daniel Kressner, Ulrich Langer, Melvin Leok, Guanglian Li, Lek-Heng Lim, Luisa Donatella Marini, Markus Melenk, Andrea Moiola, Peter Monk, Pedro Morin, Lorenzo Mascotto, Lothar Nannen, Michael Neilan, Fabio Nobile, Ricardo Nochetto, Anthony Nouy, Mario Ohlberger, Sergei Pereverzyev, Ilaria Perugia, Daniel Peterseim, Philipp Petersen, Alexander Pichler, Davide Pradovera, Dirk Praetorius, Sophie Puttkammer, Maksim Rakhuba, Holger Rauhut, Sebastian Reich, Alexander Rieder, Gianluigi Rozza, Michele Ruggeri, Gaincarlo Sangalli, Stefan Sauter, Francisco J. Sayas, Otmar Scherzer, Claudia Schillings, Reinhold Schneider, Joachim Schöberl, Andreas Schröder, Christoph Schwab, Zuoqiang Shi, Iain Smears, Benjamin Stamm, Olaf Steinbach, Rob Stevenson, Paul Stocher, Thomas Strohmer, Andrew Stuart, Li-Yeng Sung, Thomas Takacs, Rafael Vazquez Hernandez, Barbara Verfürth, Gilles Vilmart, Jonathan Weare, Marie-Therese Wolfram, Marco Zank, Jakob Zech.

Bivariant K-theory in Geometry and Physics

Organizers: Alan Carey (ANU, Canberra), Harald Grosse (U Vienna), Bram Mesland (U Bonn), Adam Rennie (U Wollongong), Walter van Suijlekom (Radboud U Nijmegen)

Dates: November 5 – 30, 2018

Budget: ESI € 28 400

Report on the programme

The aim of this programme was to capitalise on the recent upsurge of new ideas in index theory and non-commutative analysis and applications based around Kasparov's bivariant KK-theory.

In particular the development of the constructive approach to the Kasparov product initiated by Mesland and rigorously developed by numerous authors, has made the theory more computational. As a result a wide range of applications of a geometric and physical nature are being developed.

Bringing together experts in Kasparov's theory and those working in applications, particularly to physics, with the intention of sparking new collaborations and developments is the main rationale for the programme.

Topological phases of matter was the largest area of application represented at the workshop, but there were also representatives from time-signal analysis, gauge theory and Lorentzian geometry.

The mathematical topics covered ranged from the foundations of Kasparov theory, through the Baum-Connes conjecture and representation theory.

Activities

Weeks one and two of the programme had a deliberately light schedule of talks to facilitate research and interaction. With one talk a day to bring the participants together, the rest of the day could be profitably used for research.

The third week of the program was a masterclass on Kasparov's bivariant theory and its applications to topological phases of matter and Lorentzian geometry.

The main speakers were Chris Bourne (topological phases and KK), Emil Prodan (topological phases and meta-materials), Jens Kaad (introduction to the Kasparov product), Koenraad van den Dungen (Applications of Kasparov theory to Lorentzian geometry). Several lectures were presented as a warm up by the organizers Bram Mesland and Adam Rennie to ensure the students had adequate background.

A highlight was a general mathematical talk by Professor Nigel Higson giving an introduction to some ideas of non-commutative geometry.

The final week was devoted to a research workshop. Specialist presentations were given across the broad range of topics of the conference.

Specific information on the programme

The master class was very well attended, and the response was enthusiastic. There is a strong movement to learn the techniques presented in the master class, and as there are no introductory texts this master class was very timely.

In particular, many young physicists are taking up the tools of non-commutative geometry as the most natural and powerful tool for the description of topological phases.

Outcomes and achievements

A host of collaborative work was begun during the programme.

The first week saw some concentrated work in non-commutative field theory between Grosse and Wulkenaar and between Grosse and Dabrowski.

Long term projects between Mesland and Rennie were continued throughout the programme, a new project between Mesland, Rennie and Goffeng was begun in the final week, while some long term projects were completed by Goffeng, Rennie, Usachev and Bourne, Mesland. Arici, Kaad and Ćaćić, Mesland continued their ongoing research projects.

During the masterclass and workshop there was an enormous amount of collaborative discussions around the subject of topological insulators, topological metals and topological meta-materials. Key groupings include: Kellendonk, Hayashi, Thiang; Dabrowski, Thiang; Bourne, Max; Kellendonk, Bourne, Rennie; Carey, Bourne; Carey, Rennie, Schulz-Baldes. Many other discussions took place between different participants, but these indicate the most developed discussions.

During the conference a key paper was made public by van den Dungen, significantly extending the technique of the constructive Kasparov product for submersions of open manifolds. A couple of months after the programme a paper was released by Kaad addressing some of the theoretical questions around the equivalence relation defining KK-theory, which had been widely discussed at the meeting.

Over the coming months more publications related to the meeting will appear, including a general audience aritcle authored by Arici.

List of talks

Masterclass, November 19 – 23, 2018

Bram Mesland / Adam Rennie	Introduction to operator algebras and KK-theory. (I - III)
Chris Bourne	Topological phases, index theory and Kasparov theory (I - III)
Emil Prodan	Physics and applications of topological phases: How KK-theory can help? (I - III)
Jens Kaad	Recent advances in (unbounded) KK-theory (I - III)
Nigel Higson	A rapid tour through noncommutative geometry: from integral equations and the spectral theorem to the index theorem and beyond
Koen van den Dungen	Towards noncommutative Lorentzian geometry. (I + II)

Conference, November 26 – 30, 2018

Guo Chuan Thiang	Crystallographic T-duality and super Baum-Connes conjecture
Christopher Max	Bulk-boundary Correspondence of Disordered Topological Insulators and Superconductors
Francesca Arici	Gysin exact sequences from Cuntz–Pimsner extensions
Johannes Kellendonk	Secondary invariants for real K-theory from cyclic cohomology
Chris Bourne	Notes on Kitaev's $\mathbb{Z}_2$ index for Majorana fermions
Valerio Proietti	K-theory and homology in hyperbolic dynamics
Koen van Den Dungen	The Kasparov product on submersions of open manifolds
Victor Gayral	A class of locally compact quantum groups arising from Kohn-Nirenberg quantization
Sara Azzali	Discrete group actions and a weak form of the Baum–Connes conjecture
Pierre Julg	K-theory of group C*-algebras and the BGG complex
Harold Steinacker	From equivariant bundles to quantized space-times and higher-spin gauge theory
Magnus Goffeng	Constructing KMS-states from spectral triples
Franz Luef	Function spaces in noncommutative geometry

Individual talks

Hermann Schulz-Baldes	Monopole insertion and spectral flow in topological insulators
Lashi Bandara	First-order elliptic boundary value problems beyond self-adjoint induced boundary operators
Siegfried Echterhoff	The minimal exact crossed product and the Baum-Connes conjecture
Branimir Cacic	Noncommutative principal bundles in unbounded KK-theory
Paul Baum	Twisted *K*-homology
Joachim Cuntz	Linear functionals on C*-algebras and their commutative subalgebras
Ryszard Nest	Group cocycles and algebraic K-theory
Giovanni Landi	Line bundles over noncommutative spaces

Publications and preprints contributed

S. Hayashi, *Toeplitz operators on concave corners and topologically protected corner states*, arXiv:1902.01533 [math-ph].

L. MacDonald, A. Rennie, The Godbillon-Vey invariant in equivariant *KK*-theory, arXiv:1811.04603 [math.KT].

M. Goffeng, A. Rennie, A. Usachev, Constructing KMS states from infinite-dimensional spectral triples, arXiv:1811.06923 [math.OA].

C. Bourne, B. Mesland, *Index theory and topological phases of aperiodic lattices*, arXiv:1807.03972 [math.OA], DOI: https://dx.doi.org/10.1007/s00023-019-00764-9.

J. Kaad, *On the unbounded picture of KK-theory*, arXiv:1901.05161 [math.KT].

K. van den Dungen, *The Kasparov product on submersions of open manifolds*, arXiv:1811.07824 [math. KT].

Invited scientists

Francesca Arici, Are Austad, Sara Azzali, Lashi Bandara, Paul Baum, Chris Bourne, Branimir Cacic, Alan Carey, Joachim Cuntz, Ludwik Dabrowski, Koen Van den Dungen, Siegfried Echterhoff, Krzysztof Gawedzki, Victor Gayral, Magnus Goffeng, Harald Grosse, Stefan Haller, Shin Hayashi, Nigel Higson, Michel Hilsum, Alexander Hock, Pierre Julg, Jens Kaad, Johannes Kellendonk, Giovanni Landi, Gi-hyun Lee, Franz Lief, Christopher Max, Lachlan MacDonald, Bram Mesland, Sophia Emma Mikkelsen, George Nadareishvili, Ryszard Nest, Ossi Niemimäki, Emil Prodan, Valerio Proietti, Adam Rennie, Alessandro Rubin, Hermann Schulz-Baldes, Dave Shantanu, Luuk Stehouwer, Harold Steinacker, Tom Stoiber, Guo Chuan Thiang, Teun van Nuland Alexandr Usachev, Jordy Timo van Velthoven, Christian Voigt, Raimar Wulkenhaar, Shoji Yokura, Robert Yuncken, Rudolf Zeidler, Marcel Zimmer.

Workshops organized independently of the main programmes

Mathematical Challenges of Structured Function Systems

Organizers: Maria Charina (U Vienna), Karlheinz Gröchenig (U Vienna), Mihai Putinar (UC, Santa Barbara), Joachim Stöckler (TU Dortmund)

Dates: March 19 - 23, 2018

Budget: ESI € 10 720

Report on the workshop

Activities

Structured function systems are sequences of distinguished elements of a complete function space that can serve as coordinate components (orthogonal bases, Riesz bases, frames) for more elusive functions. Besides orthogonal bases of harmonics, polynomials or almost periodic functions, wavelets of many sorts and frames of entire functions have reached an impressive array of applications (in signal processing, image reconstruction, remote sensing) and also have marked some purely theoretical topics (singular integrals, spectral analysis).

In spite of the maturity of the subject and notable recent advances there are many clear-cut mathematical questions about such structured function systems. The workshop addressed two directions of such mathematical challenges in wavelet theory and in time-frequency analysis, with an emphasis on the connection of different mathematical areas. Accordingly the list of participants consisted of experts in wavelet theory and real algebraic geometry on the one hand, and experts in Gabor frames and complex analysis and special functions on the other hand.

The first main topic of the workshop was the construction of tight wavelet frames via the so-called unitary extension principle (UEP), a technique developed over the last decades by Daubechies, Ron, Shen and perfected by one of the organizers (J.S.). Basically, the UEP reduces the structure of the wavelet mask, via Fourier transform, to a purely algebraic problem living on a multi-dimensional torus. The main technical lemma in the framework of UEP is the factorization of a structured matrix valued trigonometric polynomial into a sum of hermitian squares. The latter is a major theme at the crossroads of function theory, operator theory and control of dynamical systems. The workshop put several experts on algebraic wavelet constructions in contact with experts in function theory in the poly disk (Bickel, Knese) and operator theory (Dym, Langer).

The second main topic were open problems in time-frequency analysis, notably the precise understanding of Gabor frames and sharp estimates of their frame bounds. In 30 years of research only few families of basic functions have been identified for which a complete characterization of all Gabor frames over a (rectangular) lattice is known. Although these basic functions are all totally positive in the sense of approximation theory, each subclass required a completely different proof methods. Obviously our understanding is rather limited and methods are currently taken from complex analysis, in particular the theory of entire functions in Fock space. The workshop therefore brought several complex analysts (Borichev, Lyubarskii, Ortega-Cerdà) in contact with time-frequency experts.

Specific information on the workshop

The workshop consisted of twenty talks of either one hour or 40 minutes (for more specialized talks). Upon the request of the organizers most talks were blackboard talks in order to foster mathematical insight. The participants put in considerable effort to deliver clear and enlightening talks about their subjects.

As the group of participants was extremely heterogeneous and consisted of experts from several apparently disconnected fields, the workshop started with three survey talks to provide the mathematical context in which the different fields could interact. The surveys were on the topics of applied Hermitean positivity, open problems in time-frequency analysis, and algebraic constructions of wavelet frames. Each survey talk was juxtaposed with a complementary methodological talk: Harry Dym about *J*-inner functions, J. Ortega-Cerdà about sampling and interpolation in complex analysis, and Kelly Bickel on canonical transfer function realizations.

The schedule left ample time for informal discussion, and led to intensive interaction between researchers who had not even known each other before the workshop.

Among the workshop participants were several young researchers (several Ph.D. students or within five years after their Ph.D.): K. Bickel, M. Faulhuber, K. Mönius, M. Lopez Quijorna, A. Viscardi, F. Waschbichler. Three of them, Kelly Bickel, Markus Faulhuber, and Maria Lopez Quijorna gave a talk.

The workshop was attended eagerly by members of the local community, both from the numerical harmonic analysis group, the complex analysis group at the University of Vienna, the Acoustics Research Institute, and Vienna Technical University: L D. Abreu, O. Constantin, M. Ehler, H. Feichtinger, F. Haslinger, A. Klotz, S. Koppensteiner, H. Langer, T. Mejstrik, David Rottensteiner, T. Peters.

Outcomes and achievements

M. Charina, H. Dym, M. Putinar and J. Stöckler discussed several open problems in wavelet frame theory.

A larger group consisting of K. Bickel, M. Charina, C. Conti, M. Cotronei, G. Knese, M. Putinar and T. Sauer started their cooperation to link system theory with constructions of multivariate multi-wavelets.

A. Viscardi and J. Stöckler discussed characterizations of Besov spaces via semi-regular tight wavelet frames based of subdivision. The preprint should be finished end of June and will acknowledge ESI.

K. Gröchenig, A. Haimi, J.-L. Romero, and J. Ortega-Cerdà continued to work on the problem of strict density conditions for sampling and interpolation in generalized Fock spaces. The preprint will acknowledge ESI.

A. Borichev, K. Gröchenig, Y. Lyubarskii and J.-L. Romero spent the free afternoon discussing new problems in entire functions that arise from the theory of Gabor frames, for instance sampling in subspaces of Bargmann-Fock space and the corresponding zero sets.

Kolountzakis was able to help V. Protasov to settle a computational question about tiling.

M. Charina and V. Protasov continued their study of the approximation properties of structured functions with level-dependent shift-invariance. They plan to finish their joint manuscript with N. Dyn soon and will acknowledge ESI.

List of talks

Mihai Putinar	Applied Hermitian positivity
Harry Dym	*J*-inner functions and interpolation problems
Karlheinz Gröchenig	Problems in time-frequency analysis
Joaquim Ortega-Cerda	Sampling and interpolation problems in complex analysis
Joachim Stöckler	Algebraic methods for the construction of multivariate wavelet frames
Mariantonia Cotronei	(Multi)wavelets and system theory
Kelly Bickel	Canonical transfer function realizations
Greg Knese	Moment problems on the torus and sums of squares
Tomas Sauer	Discrete directional transforms and anisotropy
Alexander Borichev	Reproducing kernels in Fock spaces
Markus Faulhuber	A Weltkonstante in time-frequency analysis
Qiyu Sun	Phaseless sampling and reconstruction of real signals
Mihalis Kolountzakis	Computational questions about translational tiling
Ole Christensen	Aspects of frame theory on LCA groups
Jakob Lemvig	System bandwidth and the existence of generalized shift-invariant frames
Yurii Lyubarskii	Lower frame bounds for incomplete lattices
Jose Luis Romero	Sampling, Gabor Frames, and totally positive functions
Konrad Schmüdgen	The truncated moment problem
Maria Lopez Quijorna	Polynomial optimization with the truncated GNS construction
Karl-Mikael Perfekt	The spectrum of the Neumann-Poincare operator on domains with corners

Publications and preprints contributed

K.-M. Perfekt, *The transmission problem on a three-dimensional wedge*, arXiv:1805.12544 [math.AP].

Invited scientists

Luis Daniel Abreu, Kelly Bickel, Alexander Borichev, Joaquim Ortega Cerd'a, Maria Charina, Ole Christensen, Costanza Conti, Mariantonia Cotronei, Harry Dym, Markus Faulhuber, Hans Georg Feichtinger, Karlheinz Gröchenig, Philipp Grohs, Antti Sakari Haimi, Friedrich Haslinger, Philippe Jaming, Kurt Jetter, Gregory Knese, Mihalis Kolountzakis, Sarah Koppensteiner, Jakob Lemvig, Maria Lopez Quijorna, Yurii Lyubarskii, Katja Moenius, Karl-Mikael Perfekt, Vladimir Protasov, Mihai Putinar, Jose Luis Romero, Tomas Sauer, Claus Scheiderer, Konrad Schmüdgen, Thomas Strohmer, Joachim Stöckler, Qiyu Sun, Alberto Viscardi, Florian Waschbichler.

Matrix Models for Noncommutative Geometry and String Theory

Organizers: Denjoe O'Connor (Dublin Inst. for Advanced Studies), Jun Nishimura (KEK, Tsukuba), Harold Steinacker (U Vienna), Asato Tsuchiya (Shizuoka U)

Dates: July 9 – 13, 2018

Budget: ESI € 14 720,
COST QSPACE € 1 230.

Report on the workshop

About 20 years ago, two matrix models known as IKKT and BFSS models were proposed as constructive definition of string- or M-theory. These are maximally supersymmetric multi-matrix models of Yang-Mills type, which generalize the more traditional random matrix models

which played an important role in many contexts such as 2-dimensional gravity, combinatorics and quantum chaotic systems. These new models share many of the rich aspects of string theory, yet they have a non-perturbative and constructive definition. Relations to noncommutative geometry, Yang-Mills gauge theory, branes and supergravity were quickly uncovered.

Following an initial period of rapid discoveries, there has been steady and ongoing progress by various groups working on different aspects of these and related multi-matrix models. One remarkable recent development was the observation (by Kim, Nishimura, Tsuchiya and collaborators) of a 3+1-dimensional geometry arising in large-scale numerical simulations of the IKKT model, which was interpreted as an "expanding universe". Novel and physically promising new solutions were found, and progress was made on understanding the phase structure of these and related models and on their relation to holography and black holes.

These development provide renewed motivation to push the further development of the matrix model approach as a possible foundation of the theory of fundamental interactions. To interpret the numerical simulations and to understand the emerging geometry, a suitable notion of matrix geometry and new methods to analyse them are required. This is also important for a better understanding of the relation with string theory and axiomatic versions of noncommutative geometry. Meanwhile, new ideas such as holography came into prominence, which provide useful insights also in the present context of matrix models. All these developments called for a dedicated meeting.

The aim of this workshop was to gather scientists working on various aspects of these and related topics, in order to assess the current status and to foster the further development and discussion of these and related models, and to initiate new ideas and collaborations. The emphasis was on the physical prospects and aspects of the models, while including mathematical topics which should be useful in this context. The idea was to mix people working on the core topics of matrix models with researches working in different but nearby subjects.

A further goal of the workshop was to raise the awareness of various aspects and connections between matrix models, noncommutative geometry and string theory in a broader context, and thereby to spark a renewed research effort.

Activities

The workshop was started by an overview talk by Hikaru Kawai, which was aimed towards a broader audience. This talk explained the idea of the IIB matrix model, and discussed the various problems and prospects, as well as different possibilities for how to extract geometry and physics.

The talks were grouped thematically. The first day was focused on basic and non-perturbative aspects of matrix models, including recent progress of numerical simulations (Nishimura, Tsuchiya) and related techniques (Fukuma), a demonstration of a dedicated software package (Gutleb), and the origins of the models (Kawai, Hoppe).

On day 2, the concepts of "matrix geometry" or "fuzzy geometry" and examples were discussed in several talks (Stern, Steinacker, Buric, Ishiki). This includes 4-dimensional Euclidean spaces with maximal isometry, but also Lorentzian spaces such as a fuzzy de Sitter space, and cosmological space-times with FRW geometry. This opens up promising new perspectives. Physical applications and aspects of field theory and entanglement entropy on fuzzy spaces were discussed (Karczmarek, Manolakos).

Day 3 provided reviews of closely related models and methods including the SYK model (Ferrari), renormalisation group methods (Koslowski), and an approach to tensionless strings was

also discussed (Shimada). The connection with more axiomatic approaches to noncommutative geometry was addressed by Glaser, who discussed a different approach to random noncommutative geometry.

The conference dinner took place at the Heurigen Zimmermann.

Day 4 was largely focused on gauged quantum matrix models, on their holographic duals and on black holes in matrix models (Berenstein, Hanada), membrane models in other backgrounds, holography and phase transitions in numerical simulations (O'Connor, Filev) and aspects of entanglement in spin chains (Sugino).

Finally on day 5, some results from neighbouring geometrical and algebraic topics were presented (Ramgoolam, Chatzistavrakidis), including a formulation of gravity on Poisson manifolds in relation with double field theory (Watamura). D. Karabali and P. Nair discussed the relation of covariant fuzzy spaces to the quantum Hall effect in 4 dimensions, as well as possible approaches to gravity from that perspective.

Apart from the talks, most importantly the meeting provided ample opportunities for discussions in smaller groups with similar research focus. For example, an informal discussion meeting was held on July 12 after the last talk, focusing on the new numerical simulations, the prospects of the cosmological solutions, and membrane quantisation. Numerous possible projects were discussed in smaller groups.

Specific information on the workshop

A number of young researchers attended the workshop:

Yuhma Asano (DIAS Dublin & KEK Tsukuba)

Samuel Kovacik (DIAS Dublin)

Juraj Tekel (Comenius University Bratislava)

Mauro D'Arcangelo (Nottingham University)

Lisa Glaser (Nijmengen University)

George Manolakos (National Technical University Athens)

Marcus Sperling (University of Vienna)

Timon Gutleb (University of Vienna)

Outcomes and achievements

The meeting was very useful and important for many reasons. One point is that many of the researchers in this subject are based in widely separated areas of the globe. Therefore, such focused meetings are very valuable to foster contacts and collaborations. Many topics have been discussed informally during breaks and outside of the official program in smaller groups.

Quite importantly, numerous new and so far unpublished results were presented and discussed during this workshop. This includes recent numerical simulations which exhibit richer geometries using sophisticated Langevin methods. Novel types of classical solutions were presented. Several talks provided useful links with methods from other contexts, such as renormalisation group methods, holography, spin chains, and many others. All this is very valuable for the on-going research and for future directions.

The meeting exhibited the various research activities in this context, which provided an important stimulus and orientation for further work. Numerous topics for further work and col-

laborations were discussed informally during the meeting. Some follow-up visits were already established (e.g. Karczmarek and Steinacker), and further collaborations will surely be initiated by this workshop.

Finally, (most of) the slides of the talks are made available on the homepage of the workshop.

List of talks

Hikaru Kawai	Problems and prospects of the IIB matrix model
Jun Nishimura	Space-time structure in the Lorentzian type IIB matrix model
Asato Tsuchiya	Emergence of chiral zero modes in the Lorentzian type IIB matrix model
Masafumi Fukuma	Distance between configurations in MCMC simulations and the emergence of AdS geometry in the simulated tempering algorithm
Jens Hoppe	Fundamental Structures of M Theory
Timon Salar Gutleb	BProbe: a tool to measure matrix geometries
Allen Stern	Signature change in matrix model solutions
Harold Steinacker	Quantized cosmological spacetimes and higher spin in the IKKT model
Goro Ishiki	Diffeomorphism for fuzzy spaces
Maja Buric	Fuzzy geometry via noncommutative frame formalism: fuzzy de Sitter space
Joanna Karczmarek	Entanglement entropy on the noncommutative sphere
George Manolakos	Three-dimensional gravity as a gauge theory on noncommutative spaces
Frank Ferrari	On Melonic Matrix Models and SYK-like Black Holes
Tim Koslowski	The continuum limit of matrix models with the FRGE
Hidehiko Shimada	Remarks on difference between membrane theory and its matrix regularisation
Lisa Glaser	Simulating the 'Quanta of geometry'
David Berenstein	Partial deconfinement phases in gauged multi-matrix quantum mechanics
Masanori Hanada	Some real-time aspects of quantum black hole
Denjoe O'Connor	Phase transitions in the BMN matrix model
Veselin Filev	Phase structure of a holographic defect field theory with a domain wall
Fumihiko Sugino	Highly entangled quantum spin chains and their extensions by semigroups
Sanjaye Ramgoolam	Branes, Dominoes and Words
Athanasios Chatzistavrakidis	T-Duality, fluxes and noncommutativity in closed string theory
Satoshi Watamura	Contravariant gravity and twisted Poisson structure
Dimitra Karabali	Quantum Hall effect: An effective action for all dimensions
V. Parameswaran Nair	Coherent States, Thermofield Dynamics and Gravity

Publications and preprints contributed

A. Stern and C. Xu, *Signature change in matrix model solutions*, arXiv:1808.07963 [hep-th].

Invited scientists

Rashid Ahmad, Yuhma Asano, David Berenstein, Maja Buric, Ursula Carow-Watamura, Athanasios Chatzistavrakidis, Mauro D'Arcangelo, Frank Ferrari, Veselin Filev, Stefan Fredenhagen, Masafumi Fukuma, Lisa Glaser, Timon Salar Gutleb, Masanori Hanada, Giorgio Immirzi, Goro Ishiki, Dimitra Karabali, Joanna Karczmarek, Hikaru Kawai, Tim Koslowski, Samuel Kovacik, Seckin Kurkcuoglu, George Manolakos Jun Nishimura, V. Parameswaran Nair, Denjoe O'Connor, Peter Presnajder, Sanjaye Ramgoolam, Akifumi Sako, Hidehiko Shimada, Markus Sperling, Harold Steinacker, Allan Stern, Fumihiko Sugino, Andreas Sykora, Juraj Tekel, Asato Tsuchiya, Satoshi Watamura, George Zoupanos.

New Trends in the Variational Modeling of Failure Phenomena

Organizers: Elisa Davoli (U Vienna), Manuel Friedrich (U Münster), Riccardo Scala (U Lisbon)

Dates: August 20 – 24, 2018

Budget: ESI € 16 160,
FWF Project F65 € 1641.

Report on the workshop

Understanding the failure behaviour of materials is currently among the most fascinating challenges lying at the interface between mathematics, physics, and materials science. Macroscopic phenomena such as plasticity, damage or fracture are considered to be the result of atomistic interactions and effects occurring on mesoscopic scales. Characterising the interplay of such different material scales is therefore a key problem for the description of the physics behind the phenomena. This leads to a variety of interesting challenges spanning from fundamental modeling issues to rigorous mathematical foundations of the theory and their versatility to simulations.

A comprehensive mathematical understanding of failure phenomena relies on a variety of different techniques, and on the combination of ideas from various fields including continuum mechanics, calculus of variations, geometric measure theory, partial differential equations, and nonlinear functional analysis.

The workshop has dealt with different themes, spanning from modeling questions for failure phenomena to the underlying mathematical theory. Topics that have been addressed include:

- Variational modeling of perfect, finite, and crystal plasticity
- Relation of different plasticity models and their range of validity
- Motion of dislocation lines and interfaces; pinning and depinning
- Modeling of defects in the passage from discrete-to-continuum
- Relation of dislocations and finite plasticity; multiscale aspects.
- Quasistatic and dynamic evolution of cracks
- Brittle, cohesive and adhesive behavior in fracture and delamination
- Failure of plasticity models in the presence of damage, and cracks

Activities

The workshop consisted of 26 talks both by internationally renowned experts in the field and by younger scientists. In particular, there have been 4 keynote lectures held by I. Fonseca, G. Francfort, G. Leoni, and T. Roubíček, meant to be addressed to a broader audience, and to provide a general overview on the main new trends and open problems in the field. The schedule of the workshop has been organized in such a way to leave enough time for discussions among the participants, with an average of 5 talks per day and two free afternoons.

Specific information on the workshop

The complete list of young researchers who attended the workshop, attending the talks, and interacting with the other participants, are detailed below:

Stefano Almi (Post-doc)

Annika Bach (Post-doc)

Sandro Belz (Prae-doc)

Katharina Brazda (Prae-doc)

Marin Bužančíč (Prae-doc)

Marcello Carioni (Post-doc)

Nicola De Nitti (Prae-doc)

Silvio Fanzon (Post-doc)

Peter Gladbach (Post-doc)

Martin Jesenko (Post-doc)

Shokhrukh Kholmatov (Post-doc)

Leonard Kreutz (Post-doc)

Petar Kunstek (Prae-doc)

Pan Liu (Post-doc)

David Melching (Prae-doc)

Anastasia Molchanova (Post-doc)

Gianluca Orlando (Post-doc)

Valerio Pagliari (Prae-doc)

Lorenzo Portinale (Prae-doc)

Michele Ruggeri (Post-doc)

Viktor Shcherbakov (Post-doc)

Lara Trussardi (Post-doc)

Josip Žubrinić (Prae-doc).

In addition, Peter Gladbach (Post-doc) and Martin Jesenko (Post-doc) have been speakers in the workshop.

Outcomes and achievements

The workshop has been organized in such a way as to provide all the participants with the opportunity to interact with each other. A selection of the collaborations that the participants have begun or continued at the institute is provided below:

- Stefano Almi has scientifically interacted with Matteo Negri;

- Katharina Brazda has talked to Marco Morandotti (about his publication on cell membranes), as well as to Tomas Roubíček and Martin Kružík (about spatial/material descriptions in continuum mechanics);

- Carolin Kreisbeck has discussed an ongoing project with Elisa Davoli (University of Vienna) and Rita Ferreira (KAUST, Saudi Arabia) on "Homogenisation in BV of a model for layered composites in finite crystal plasticity";

- Leonard Kreutz has scientifically interacted with Manuel Friedrich, as well as Francesco Solombrino, and Giuliano Lazzaroni;

- Martin Kružík has discussed his ongoing project with Manuel Friedrich (viscoelastic materials), Elisa Davoli and Paolo Piovano (dimension reduction for magnetoelastic materials) and Edoardo Mainini (phase-field approximation of sharp interface models in Lagrangian-Eulerian formulation);

- Giuliano Lazzaroni has collaborated with Stefano Almi and Ilaria Lucardesi on the topics of crack propagation in planar elasticity, with Riccarda Rossi quasistatic evolution for elastoplastic-damage models, and with Francesco Solombrino on dynamic crack propagation. In addition he has initiated possible collaborations with Paolo Piovano on discrete models with dislocations, and with Riccardo Scala on wave equation with obstacles;

- Ilaria Lucardesi has interacted with Stefano Almi on the topic of dislocations and energy release rate;

- Anastasia Molchanova has discussed her Lise-Meitner proposal with Elisa Davoli, and has interacted with Viktor Shcherbakov and Dorothee Knees on the topics of nonlinear elasticity and quasiconformal analysis;

- Marco Morandotti has discussed ongoing projects with Ilaria Lucardesi and Riccardo Scala (regarding dislocations in solids and the modelling of the upscaling under conditions that grant confinement in the material) and with Elisa Davoli (on a project on thin films, where they study a Cahn-Hilliard-type model for the formation of thin films via the Langmuir-Blodgett transfer). He has started discussing with Francesco Solombrino on a possible joint project regarding the dynamics of a multi-agent system involving the creation and destruction of leaders and followers in a population. Finally, he has planned to work with Carolin Kreisbeck on projects regarding the application to the theory of structured deformations;

- Matteo Negri has taken the chance to talk with Riccardo Scala on an ongoing project about dynamic cohesive models with constraint;

- Anja Schlömerkemper has worked on a joint paper together with Julian Fischer and Marcello Carioni on the passage of discrete to continuous systems for a one-dimensional chain of atoms with external forces.

- Elisa Davoli has discussed an ongoing project on delamination and dimension reduction with Riccarda Rossi, and one on homogenisation and dimension reduction in elastoplasticity with Igor Velčić and Marin Bužančić. She has worked with Manuel Friedrich on solid-solid phase transitions, and discussed with Irene Fonseca and Pan Liu about an ongoing project on image reconstruction.

- Riccardo Scala has discussed with Nicolas Van Goethem on their ongoing project on dynamics and statics of continuum dislocations. He has also interacted together with Gianluca Orlando and Vito Crismale on a possible collaboration on the analysis of linearized plasticity models with damage.

List of talks

Irene Fonseca	Mathematical Analysis of Novel Advanced Materials
Marco Morandotti	Discrete-to-continuum limits for dislocations: results in one and two dimensions
Francesco Solombrino	Multiscale analysis of singularly perturbed finite dimensional gradient flows: the minimizing movement approach
Riccarda Rossi	Visco-Energetic solutions to rate-independent systems in finite-strain plasticity and brittle fracture
Dorothee Knees	Convergence analysis of time-discretization schemes for rate-independent systems
Matteo Negri	Alternate minimizing schemes for the evolutions of phase-field fractures
Gilles Francfort	The ubiquitous role of stability in solids with defects
Nicolas Van Goethem	Around the incompatibility operator and a new model of elasto-plasticity
Carolin Kreisbeck	Asymptotic rigidity of layered structures and its applications in homogenization theory
Rita Ferreira	Homogenization in BV of a model for layered composites in finite crystal plasticity
Anja Schlömerkemper	Homogenization in the passage from discrete to continuous systems - fracture in composite materials
Barbara Zwicknagl	Variational models for stress-free martensitic nuclei
Giovanni Leoni	A new class of fractional Sobolev spaces
Edoardo Mainini	Atomistic potentials and the Cauchy-Born rule for carbon nanotubes
Peter Gladbach	Optimal transport with dynamic density constraint
Martin Jesenko	Non-trivial pinning threshold for an evolution equation involving long range interactions
Marcello Ponsiglione	Gamma-convergence of the Heitmann-Radin sticky disc energy to the crystalline perimeter and other variational models for polycrystals
Lucia De Luca	A minimization approach to the wave equation on time-dependent domains
Ilaria Lucardesi	Energy release rate and stress intensity factors in planar elasticity in presence of smooth cracks
Alessandro Giacomini	Local minimality results for the Mumford-Shah functional via monotonicity
Martin Kružík	A phase-field approach to Eulerian interfacial energies
Caterina Zeppieri	Stochastic homogenization of free-discontinuity problems
Tomáš Roubíček	Dynamical damage and phase-field fracture models
Gianluca Orlando	A model for damage subject to elastic fatigue
Viktor Shcherbakov	Conservation laws and energy release rates for interfacial cracks in fiber-reinforced composites
Giuliano Lazzaroni	On the $1d$ wave equation in time-dependent domains and the problem of debond initiation

Publications and preprints contributed

M. Bonacini, E. Davoli, M. Morandotti, *Analysis of a perturbed Cahn-Hilliard model for Langmuir-Blodgett films*, arXiv:1809.07566 [math.AP].

I. Lucardesi, M. Morandotti, R. Scala, D. Zucco, *Upscaling of screw dislocations with increasing tangential strain*, arXiv:1808.08898 [math.AP].

E. Davoli, R. Ferreira, C. Kreisbeck, *Homogenization in BV of a model for layered composites in finite crystal plasticity*, arXiv:1901.11517 [math.AP].

E. Davoli, I. Fonseca, P. Liu, *Adaptive image processing: first order PDE constraint regularizers and a bilevel training scheme*, arXiv:1902.01122 [math.AP].

E. Davoli, M. Friedrich, *Two-well rigidity and multidimensional sharp-interface limits for solid-solid phase transitions*, Submitted, 2018 (Preprint available on http://cvgmt.sns.it/paper/4071/).

Invited scientists

Stefano Almi, Annika Bach, Sandro Belz, Katharina Brazda, Marin Bužančić, Marcello Carioni, Elisa Davoli, Lucia De Luca, Nicola De Nitti, Rita Ferreira, Julian Fischer, Irene Fonseca, Gilles Francfort, Silvio Fanzon, Manuel Friedrich, Alessandro Giacomini, Peter Gladbach, Martin Jesenko, Shokrukh Kholmatov, Dorothee Knees, Carolin Kreisbeck, Leonard Kreutz, Martin Kruzik, Petar Kunstek, Giuliano Lazzaroni, Giovanni Leoni, Pan Liu, Ilaria Lucardesi, Edoardo Mainini, David Melching, Marco Morandotti, Anastasia Molchanova, Matteo Negri, Gianluca Orlando, Valerio Pagliari, Paolo Piovano, Marcello Ponsiglione, Riccarda Rossi, Tomas Roubicek, Michele Ruggeri, Riccardo Scala, Anja Schlömerkemper, Viktor Shcherbakov, Francesco Solombrino, Lara Trussardi, Nicolas Van Goehtem, Igor Velčić, Caterina Zeppieri, Josip Žubrinić, Barbara Zwicknagl.

Geometric Correspondences of Gauge Theories

Organizers: Giulio Bonelli, Ugo Bruzzo, Jacopo Stoppa, Alessandro Tanzini (all: SISSA, Trieste), Maxim Zabzine (U Uppsala), local organizer: Harald Grosse (U Vienna)

Dates: August 27 – September 7, 2018

Budget: ESI € 15 600,
SISSA € 3 015.

Report on the workshop

The event had the format of a school followed by a conference. It was focused on the following topics:

- Donaldson-Thomas invariants for 3- and 4-folds, Gopakumar-Vafa and Vafa-Witten variants
- Topological strings
- Quiver gauge theories

Activities

School lectures, Minicourses:

- **Yalong Cao, Donaldson-Thomas gauge theory on Calabi-Yau 4-folds.** The course started with a review of gauge theories on various dimensions, especially in dimension 3 and 4, and their complex versions. Specifically, a complexification of Donaldson theory on 4-dimensional CY's was discussed in detail; the corresponding counting invariants are called DT4 invariants as they are the 4-fold analogue of DT invariants originally defined on CY 3-folds. Applications and examples were discussed.

- **Marcos Mariño, Topological Strings and Quantum Mechanics.** This minicourese discussed a general correspondence which associates a non-perturbative quantum-mechanical operator to a toric Calabi-Yau manifold; an explicit formula for its spectral determinant in terms of an M-theoretic version of the topological string free energy is conjectured. An exact quantization condition for the operator spectrum, in terms of the

vanishing of a generalized theta function, is derived. The perturbative part of this quantization condition is given by the Nekrasov-Shatashvili limit of the refined topological string, but there are non-perturbative corrections determined by the conventional topological string. The predictions for the spectrum agree with the existing numerical results. Physically, these results provide a non-perturbative formulation of topological strings on toric Calabi-Yau manifolds, in which the genus expansion emerges as a 't Hooft limit of the spectral traces. Since the spectral determinant is an entire function on the moduli space, it leads to a background-independent formulation of the theory. Mathematically, the results lead to precise, surprising conjectures relating the spectral theory of functional difference operators to enumerative geometry.

- **Yukinobu Toda, Gopakumar-Vafa invariants for Calabi-Yau 3-folds and 4-folds.** The course was about sheaf theoretic definitions of Gopakumar-Vafa invariants for Calabi-Yau 3-folds and 4-folds. In the case of CY 3-folds, GV invariants were defined using perverse sheaves of vanishing cycles on moduli spaces of one dimensional stable sheaves. This definition is a modification of earlier definitions by Kiem-Li and Hosono-Saito-Takahashi. Then GV invariants were shown to agree with Pandharipande-Thomas invariants for local surfaces with irreducible curve classes. A counter-example to the Kiem-Li conjectures, where the invariants match the predicted answer, was given. In the case of CY 4-folds, genus zero GV invariants, which were recently introduced, were described as Donaldson-Thomas invariants for CY 4-folds previously defined by Cao-Leung and Borisov-Joyce; they are conjecturally related to genus zero Gromov-Witten invariants via a multiple cover formula.

- **Richard Thomas, (Refined) Vafa-Witten invariants for projective surfaces.** The aim of the course was to define refined Vafa-Witten invariants of projective surfaces, and calculate them in some cases. This constitutes different projects joint with Yuuji Tanaka, Davesh Maulik and Amin Gholampour. Sketch programme: 1. Virtual cycles and localisation in cohomology. 2. Virtual structure sheaves and localisation in K-theory. 3. Vafa-Witten invariants: stable case, semistable case, and refinement. 4. Degeneracy loci and Carlsson-Okounkov operators in cohomology and K-theory.

Additional short lectures courses:

- Taro Kimura, Quantum algebras from quiver gauge theory
- Masahito Yamazaki, Integrability from 4d Chern-Simons Theory

Specific information on the workshop

Young participants
Students: Nadir Fasola
Postdocs: Nicolò Piazzalunga, Antonio Sciarappa

Outcomes and achievements

One of us (H. G.) had lively discussions especially with Marcos Mariño on the "Topological Strings and Quantum Mechanics" subject, discussions with Andrei Mironov and Alexei Morozov on their work are acknowledged too.

List of talks

School: August 27 – 31, 2018

Yalong Cao	Donaldson-Thomas gauge theory on Calabi-Yau 4-folds, I - IV
Marcos Mariño	Topological Strings and Quantum Mechanics, I - IV
Taro Kimura	Quantum algebras from quiver gauge theory, I - IV
Andrei Mironov	Correlators in tensor models and Kroneker characters
Alexei Morozov	On the analogue of Schur functions for plane partitions

Conference: September 3 – 7, 2018

Yukinobu Toda	Gopakumar-Vafa invariants for Calabi-Yau 3-folds and 4-folds, I - IV
Masahito Yamazaki	Integrability from 4d Chern-Simons Theory, I - II
Fabrizio Nieri	Localization on compact spaces, q-W algebras and modularity
Martijn Kool	New calculations in Vafa-Witten theory
Can Kozcaz	Refined topological branes
Richard Thomas	(Refined) Vafa-Witten invariants for projective surfaces, I - IV
Tamas Hausel	Mirror symmetry with branes by equivariant Verlinde formulae
Guglielmo Lockhart	Universal features of 6d BPS strings
Jan Manschot	Supersymmetric gauge theories and (iterated) integrals of modular forms
Shlomo Razamat	Compactification of minimal 6d SCFTs on Riemann surfaces
Nicolo' Piazzalunga	Magnificent Four with Color
Kazunobu Maruyoshi	Supersymmetry enhancing RG flow and Argyres-Douglas theories
Antonio Sciarappa	Wilson loops, Wilson surfaces and S-duality

Publications and preprints contributed

J. Stoppa, *A note on BPS structures and Gopakumar-Vafa invariants*, arXiv:1812.07454 [math.AG].

Invited scientists

Giulio Bonelli, Ugo Bruzzo, Yalong Cao, David Erkinger, Nadir Fasola, Harald Grosse, Tamas Hausel, Jonathan Heckman, Ekin Kaan, Taro Kimura, Johanna Knapp, Martin Kool, Can Kozcaz, Guglielmo Lockhart, Jan Manschot, Marcos Marino, Kazunobu Maruyoshi, Anton Mellit, Andrei Mironov, Alexei Morozov, Fabrizio Nieri, Nicolo Piazzalunga, Shlomo Razamat, Antomio Sciarappa, Jacopo Stoppa, Alessandro Tanzini, Richard Thomas, Yukinobu Toda, Masahito Yamazaki, Maxime Zabzine.

Moonshine

Organizers: John Duncan (Emory U, Atlanta), Anne Taormina (Durham U), Katrin Wendland (U of Freiburg), Timm Wrase (TU Vienna)

Dates: September 10 – 14, 2018

Budget: ESI € 15 200,
FWF stand alone grant P 28552 € 934,26.

Report on the workshop

Eguchi, Ooguri and Tachikawa (EOT) initiated a new era in moonshine in 2010, by observing a relationship between representations of the Mathieu group M_{24} and the elliptic genus of a K3 surface. As it ties in Calabi-Yau geometry and supersymmetric string theory, this *Mathieu moonshine* observation has generated a lot of interest and activity. By now Mathieu moonshine has been recognised as a special case of *umbral moonshine*, and several other new instances of moonshine have been discovered in recent years. The relationship between K3 (sigma model) symmetries and M_{24} has been clarified, but not in a way that resolves the EOT observation. There are many important questions that will take time to solve.

The topic of this workshop was moonshine phenomena, and should be understood in the broadest sense. Current interesting topics that we covered at the workshop are the following:

- New moonshine phenomena and potential interconnections between them.

- The search for a unified way of understanding the different moonshine phenomena and ideas towards classifying moonshine phenomena.

- Enumerative geometry of K3 surfaces and higher dimensional Calabi-Yau manifolds and their potential connection to moonshine.

- Recent developments in the study of automorphic forms and potential connections to physics.

- Black hole microstate counting and wall crossing.

- Recent developments in VOAs and CFTs in two dimensions and their applications to moonshine.

- The relation between quantum gravity in three dimensions and CFTs in two dimensions.

- Applications of moonshine to arithmetic geometry.

Recent developments in all these topics have been reflected in the selection of the seminar talks so that we did cover a wide range of ideas. This ensured that we incorporated and discussed the newest important scientific developments in this growing and exciting field during the workshop.

Activities

We decided to dedicate most of the workshop time to seminar talks given by the participants. Since we had people from all over the world (Asia, Europe and America) that do not often meet, it was useful that most participants could present their latest research results in such talks. However, since many of the participants come from different places and are involved in ongoing research projects, it was also important to leave some time for people to work on ongoing and planned future research projects. For that reason we decided to leave Wednesday and Friday afternoon free for people to work and discuss.

We also decided (as discussed below) to encourage all junior participants to give talks. In order to make this possible, we chose to have several one hour long talks but then also some special sessions with many fifteen minute talks.

In addition to the scientific activities we organized a reception on the first day of the conference so people can discuss informally and socialize. Additionally we had a workshop dinner at a

local Heuriger on Thursday night that also allowed everybody to get together in an informal manner.

Specific information on the workshop

For this workshop we tried to particular focus on PhD students and young postdocs and we encouraged all of them to give a short talk about their respective work. This was a great success, since they did an excellent job and exposed the more senior people to a variety of interesting research directions. This will also be very helpful in the future when these younger people are searching for postdoc positions and the more senior people are involved in the hiring decisions. Due to this particular focus on younger people, we ended up having sixteen talks by younger people and sixteen by more senior researchers. Overall this turned out to be a great mix.

The two free afternoons that were used for discussions and to work in smaller groups, seems to have been a very good balance between time allocated to talks and free time for the participants.

Outcomes and achievements

One goal of the workshop was to update all of the participants on the latest results obtained in moonshine. This was certainly accomplished by all the talks that were given during the workshop. This provides an important baseline on which people can build their future research.

A second goal of the workshop was to allow people to continue collaborations that have been started in the past but that they have not been able to finish, because the collaborators work at different institutes, or the project was missing input from other experts in the field, or people simply lacked the time to sit down and work because they have so many other responsibilities at their home institution. Here the workshop provided a wonderful opportunity to make progress on research projects and move them closer to publication. In particular three papers have already been finished within a few month after the workshop and these are listed below. Also other people have used the opportunity to continue ongoing research collaborations, like for example we are aware of the following ongoing collaborations on which the following participants worked during the workshop

- Sameer Murthy and Don Zagier

- Albrecht Klemm Don Zagier

- Anne Taormina, Katrin Wendland and Don Zagier

- Anne Taormina, Katrin Wendland and Sameer Murthy

- Scott Carnahan, Thomas Creutzig and Katrin Wendland

Lastly, people have also used this workshop to start new research projects that hopefully will lead to publications in the near future. In particular, a new research project has been started that involves Andreas Banlaki, Aradhita Chattopadhyaya, Abhishek Chowdhury, Justin David, Abhiram Mamandur Kidambi, Maria Schimpf, Harald Skarke and Timm Wrase.

List of talks

Don Zagier	Constructing mock modular forms with a given shadow
Sameer Murthy	Mock modular forms as torus integrals
Daniel Grumiller	Aspects of chiral gravity and AdS3/log CFT2
Michael H. Mertens	Moonshine in weight 3/2
Yingkun Li	Mock modular forms of small weights
Justin David	Applications of moonshine symmetry in string compactifications and black holes
Abhishek Chowdhury	Calabi-Yau manifolds and sporadic groups
Max Zimet	Umbral Moonshine and String Duality
Maria Schimpf	M24 Moonshine in IIA and IIB string theory
Aradhita Chattopadhyaya	Black hole degeneracies from Mathieu moonshine
Andreas Banlaki	Gromow-Witten-Invariants and Moonshine
Brandon Rayhaun	Skew-holomorphic moonshine
Vassilis Anagiannis	A module for a case of umbral moonshine
Valentin Reys	Mixed mock modular forms and BPS black hole entropy
Abhiram Mamandur Kidambi	Exact entropy and Rademacher series for orbifolded BPS black holes
Nils Scheithauer	Generalised deep holes in the vertex operator algebra associated with the Leech lattice
Victor Aricheta	Supersingular elliptic curves and moonshine
Lea Beneish	Quasimodular moonshine and arithmetic connections
Sam Fearn	A supersymmetric index for a class of 2d sigma models with large N=4 superconformal symmetry
Thomas Gemünden	Orbifolds of Lattice Vertex Operator Algebras at d=48 and 72
Fabian Kertels	Characterizing Borcherds-Kac-Moody algebras
Caner Nazaroglu	Indefinite Theta Series and Applications
Rajesh Gupta	Squashed Toric Manifolds and Mock Modular Forms
Wolfgang Riedler	Global sections of the chiral de Rham complex on Enriques surfaces
Boris Pioline	BPS black holes, wall-crossing and mock modularity of higher depth I
Sergey Alexandrov	BPS black holes, wall-crossing and mock modularity of higher depth II
Scott Carnahan	More Modular Moonshine
Bailin Song	Matheiu moonshine and K3 surfaces
Thomas Creutzig	The moonshine module and friends
Jens Funke	Indefinite theta series
Roberto Volpato	Superstrings and BKM (super-)algebras
Albrecht Klemm	Periods and quasiperiods of modular forms and D-brane masses of the quintic

Publications and preprints contributed

V. M. Aricheta, *Supersingular elliptic curves and moonshine*, arXiv:1809.0742 [math.NT].

A. Chattopadhyaya and J. R. David, *Properties of dyons in $\mathcal{N} = 4$ theories at small charges*, arXiv:1810.12060 [hep-th].

A. Banlaki, A. Chowdhury, A. Kidambi and M. Schimpf, *On Mathieu moonshine and Gromov-Witten invariants*, arXiv:1811.11619 [hep-th].

Invited scientists

Sergey Alexandrov, Vassilis Anagiannis, Victor Manuel Aricheta, Andreas Banlaki, Lea Beneish, Scott Carnahan, Aradhita Chattopadhyaya, Abhishek Chowdhury, Thomas Creutzig, Justin Raj David, John Duncan, Sam Fearn, Stefan Fredenhagen, Jens Funke, Thomas Gemünden, Daniel Grumiller, Rajesh Gupta, Gerald Höhn, Fabian Kertels, Maryam Khaqan, Albrecht Klemm, Yingkun Li, Abhiram Mamadur Kidambi, Rodrigo FarinhaMatias, Anton Mellit, Michael H. Mertens, Sameer Murthy, Caner

Nazaroglu, Boris Pioline, Brandon Rayhaun, Valentin Reys, Wolfgang Riedler, Nils Scheithauer, Maria Schimpf, Harald Skarke, Bailin Song, Anne Taormina, Roberto Volpato, Katrin Wendland, Timm Wrase, Raphaela Wutte, Don Zagier, Max Jordan Zimet, Sander Zwegers, Céline Zwikel.

Rigidity and Flexibility of Geometric Structures

Organizers: Georg Nawratil (TU Vienna), Anthony Nixon (Lancaster U), Josef Schicho (JKU Linz), Brigitte Servatius (Worcester Polytechnic Inst.)

Dates: September 24 – 28, 2018

Budget: ESI € 13 760

Report on the workshop

The mathematical study of the rigidity and flexibility of discrete structures can be traced back to classical work of Euler, Cauchy and Maxwell on the rigidity of polyhedra and skeletal frames. However in the last 5 years the subject has become particularly active, drawing on diverse areas of mathematics and engaging with a growing range of applications. The activity is driven in part by the solution of some longstanding open problems, such as the so-called Molecular Conjecture, the determination of the generic nature of global rigidity, and by connections with nearby mathematical areas, such as distance geometry and topology. Both theoretical (combinatorics, algorithms, discrete and algebraic geometry) and applied (materials geometry, robot kinematics, symbolic computation) aspects of rigidity and flexibility are flourishing and in recent years the subject in general has increased its international visibility as an active research area.

The workshop focussed on the following key topics:

- Global rigidity and the graph realisation problem (keynote talks by Leo Liberti and Louis Theran);

- Combinatorial rigidity, algorithms and enumeration problems (introductory talk by Bill Jackson, keynote talks by Meera Sitharam and Mateo Gallet);

- Flexibility of structures and linkages (introductory talk by Hellmuth Stachel, keynote talks by Ivan Izmestiev, Oleg Karpenkov and Gaiane Panina).

Global rigidity, or when a given set of edge lengths uniquely determines the shape of a graph, is of fundamental importance in applications such as wireless sensor networks and protein structure determination. Theoretically, global rigidity is understood by means of the stress matrix (a weighted Laplacian matrix). Recently fundamental results in this area have been established and analogues proved for universal rigidity (global uniqueness in all higher dimensions). These results have forged links to matrix analysis, convex optimisation and semi-definite programming which in turn suggests potentially fruitful crossover with researchers working in distance geometry. The key question in distance geometry, the graph realisation problem, takes a graph and a list of edge lengths and asks if there is a realisation of the graph in a given space with those lengths.

Generically, the rigidity of bar and joint structures in the plane is well understood (matroidal structure, inductive constructions) and efficient algorithms have been known for many years in the (German) engineering literature and in the mathematics literature. Recent results have extended the 2-dimensional theory to a wide variety of settings and incorporated new techniques from matroid theory, convex geometry and analysis. One intriguing current application worth exploring in detail is to the control of robotic formations. In higher dimensions however, particularly dimension 3, there are many open problems and no efficient algorithms.

A focus of the workshop concerned results on the number of realisations of a rigid graph, with recent advances using algebraic and tropical geometry. Another fact is that many questions on flexibility and linkages can be reduced to systems of polynomial equations. Computational examples in kinematics are frequently used as challenges for computer algebra programs for polynomial system solving. Techniques in numerical algebraic geometry should be helpful in gaining insight into structural questions on flexible/rigid frameworks.

Moreover the workshop was devoted to the flexibility of geometric structures; especially of those arising in robot kinematics. Within the last few years the Austrian community has been very active within this field and obtained many novel results by means of Bond theory, a recent technique based on compactifications of various groups describing motions in the plane or in 3-space. In this context the classification of closed serial chains and parallel manipulators, respectively, with paradoxical mobility is still an open problem. Further attention is given to the synthesis of mechanisms by using the factorization of motion polynomials over the dual quaternions. The solutions to these open issues require different techniques ranging from kinematical geometry to symbolic computation and numerical as well as classical algebraic geometry.

Activities

The workshop had 2 introductory lectures (1 hour each), 7 invited talks (1 hour each), 17 contributed talks (25 minutes each) and 19 speed talks (5 minutes each).

Specific information on the workshop

There were 48 participants, including the following 11 graduate students: Sean Dewar (Lancaster), Marc Diesse (Hochschule Heilbronn), Tiago Duarte-Guerreiro (Loughborough), Zeyuan He (Cambridge), Marina Konstantatou (Cambridge), Jan Legersky (JKU Linz), Klara Mudilova (TU Vienna), Rahul Prabhu (Florida), Arvin Rasoulzadeh (TU Vienna), Daniel Scharler (Innsbruck), Qays Shakir (University of Ireland, Galway) and the following 9 postdoctoral researchers: Remi Cocou Avohou (Jerusalem), Jose Capco (JKU Linz), Katharine Clinch (Tokyo), Matteo Gallet (RICAM, ÖAW), Georg Grasegger (RICAM, ÖAW), Grigory Ivanov (EPFL), Lefteris Kastis (Lancaster), Zijia Li (TU Vienna), Niels Lubbes (RICAM, ÖAW).

One postdoc gave a keynote presentation, 2 postdocs and 5 graduate students presented contributed talks, and 3 postdocs and 4 graduate students gave speed talks.

Outcomes and achievements

We have received the following information on collaborations arising from, or worked on during, the workshop.

- James Cruickshank, Qays Shakir and Bernd Schulze initiated a possible collaboration involving studying periodic generalisations of results of Streinu et. al on pseudo-triangulat-

ions.

- Simon Guest and Ivan Izmestiev had discussions concerning the embedding of convex polyhedra, related to an ongoing project that Guest has with Patrick Fowler, Tibor Tarnai and Florian Kovacs concerning the 'wrapping' of cubes and related polyhedra.

- During the workshop, Simon Guest and Zeyuan He had a pleasent discussion with Ivan Izmestiev and Grigory Ivanov about how to construct a flexible and infinitely extendable quadrilateral creased paper.

- Leo Liberti and Remi Cocou Avohou are looking at a mixed-integer programme mentioned in Avohou's speed talk.

- Andrea Micheletti and Leo Liberti are seeking to solve some problems related to designing tensegrity structures using optimization tools.

- Hans Christian Graf von Bothmer and Georg Nawratil discussed the incorporation of known families of flexible hexapods into the classification given in the paper "Hexapods with a small linear span", which is in preparation.

- Hans Christian Graf von Bothmer, Ivan Izmestiev and Georg Nawratil discussed an algebraic classification of flexible 3×3 Kokotsakis meshes beside the given one of Izmestiev based on elliptic functions.

- Gaiane Panina and Oleg Karpenkov discussed equilibrium stresses on piecewise linear realizations of CW-complexes and related algorithms that recognize stressability. It is worthy mentioning that equilibrium stresses together with Maxwell-Cremona corespondence exist in any dimension.

- Grigori Ivanov and Gaiane Panina discussed the problem of finding the maximal k-volume of a projection of a regular n-cross-polytope to a k-plane. It seems interesting not only to look at the maximum of the volume, but also at all the critical points, since there should be many of them, not just one minimum and one maximum.

- Ciprian Borcea and Gaiane Panina discussed Borcea's (unpublished, independent) straightforward computation of the Morse index of a cyclic polygon. This looks really interesting since straightforward computations are tricky in this framework.

- Stephen Power was able to inform participants of some of his ongoing joint projects with chemists on deformations of periodic nets and frameworks. Secondly conversations with participants (particularly with Ciprian Borcea and Louis Theran) were helpful in connections with Power's ongoing projects. Thirdly the facilities of the ESI were perfect for some intensive joint research between Power and Lefteris Kastis who were able to resolve a characterisation of the minimal 3-rigidity of triangulated Mobius strips, and the ESI will be acknowledged in their preprint nearing completion.

- Discussions between Tibor Jordan and Bernd Schulze following Schulze's talk on frameworks with coordinated edge motions resulted in some further progress in this area: one may obtain a polynomial-time algorithm for checking the generic rigidity of coordinated frameworks in the plane for an arbitrary number of coordination classes using a matroid-theoretic approach.

- Zijia Li, Daniel Scharler and Hans-Peter Schrocker made the final (but substantial) revision of the paper arxiv.org/abs/1803.06194 at ESI. It is meanwhile accepted for publication in Computational and Applied Mathematics.

- Remi Cocou Avohou, Brigitte Servatius and Herman Servatius made substantial progress in sketching out a paper on combinatorial maps on compact surfaces and establishing isomorphisms between several matroids, including rigidity matroids for graphs whose vertices are embedded on a flat torus. It should be noted that the available chalk board space in our offices was very helpful to develop and compare key examples.

- Georg Grasegger, Jan Legersky, and Meera Sitharam formulated questions about Georg and Jan's flexible Laman frameworks without joint coincidence; and ideas for potential connections with Meera's low cayley complexity frameworks (with testable genericity conditions). They did some preliminary tests on one of the questions, strengthening it to a conjecture. This would be a potential future collaboration arising from the workshop.

List of talks

Hellmuth Stachel	Between rigidity and flexibility
Bill Jackson	Rigidity of graphs and frameworks
Oleg Karpenkov	Configuration spaces of tensegrities on graphs and CW-complexes
Andrea Micheletti	Some questions on molecular structures and rigid-panel structures
Brigitte Servatius	Delta matroids and rigidity matroids for graphs and maps on surfaces
Ivan Izmestiev	Flexible Kokotsakis polyhedra and elliptic functions
Grigory Ivanov	Orthodiagonal Kokotsakis polyhedra
Zeyuan He	Rigid-foldable quadrilateral creased papers
Klara Mundilova	"Rigid" curved crease origami
Meera Sitharam	Realization Certificates for Solving Geometric Constraint Systems (and a polynomial time algorithm for planar, minimally rigid, bar-joint systems)
Jean-Marc Schlenker	Polyhedra inscribed in quadrics
Andreas Mueller	Higher-order rigidity revisited from screw theory
Louis Theran	Unlabeled generalisations of global rigidity
Ciprian Borcea	Ellipsoids and auxetics
James Cruickshank	Periodic packings of curves
Stephen Power	Counting 3-periodic nets and their isotopy classes
Matteo Gallet	Tropical geometry for minimally rigid graphs
Jan Legersky	Graphs with flexible labelings allowing injective realizations
Hans-Christian van Bothmer	Hexapods with a small linear span
Leo Liberti	Distance geometry in data science
John Owen	Symmetry, redundancy and quadratic solvability in point-line-plane frameworks
Sean Dewar	Rigidity in the normed plane
Bernd Schulze	Frameworks with coordinated edge motions
Gaiane Panina	Oriented area as a Morse function
Daniel Scharler	Rational motions with trajectories of low degree
Niels Lubbes	On an invariant for linkages

Publications and preprints contributed

V.M. Aricheta, *Supersingular Elliptic Curves and Moonshine*, arXiv:1809.07421 [math.NT].

A. Chattopadhyaya, J.R. David, *Properties of dyons in $\mathcal{N} = 4$ theories at small charges*, arXiv:1810.12060 [hep-th].

Invited scientists

Remi Cocou Avohou, Ciprian Borcea, Hans-Christian Graf von Bothmer, Jose Capco, Katharine Clinch, James Cruickshank, Sean Dewar, Marc Diesse, Matteo Gallet, Tiago Duarte-Guerreiro, Georg Grasegger, Simon Guest, Zeyuan He, Grigory Ivanov, Ivan Izmestiev, Bill Jackson, Tibor Jordán, Oleg Karpenkov, Eleftherios Kastis, Marina Konstantatou, Christoph Koutschan, Jan Legersky, Zijia Li, Leo Liberti, Niels Lubbes, Andrea Micheletti, Andreas Müller, Christian Müller, Klara Mundilova, Georg Nawratil, Anthony Nixon, John Owen, Gaiane Panina, Stephen Power, Rahul Prabhu, Arvin Rasoulzadeh, Daniel Scharler, Josef Schicho, Jean-Marc Schlenker, Hans-Peter Schröcker, Bernd Schulze, Brigitte Servatius, Herman Servatius, Qays Shakir, Meera Sitharam, Diane Souvaine, Hellmuth Stachel, Louis Theran.

E-CAM State-of-the Art Workshop: Large Scale activated Event Simulations

Organizers: Peter Bolhuis (U of Amsterdam), Christoph Dellago (U Vienna), Gerhard Kahl (TU Vienna)

Dates: October 1 – 3, 2018

Budget: ESI € 3 120,
CECAM Nodes Vienna and Lausanne € 7 161.

Report on the workshop

Activities

Running on powerful computers, large-scale molecular dynamics (MD) simulations are used routinely to simulate systems of millions of atoms providing crucial insights on the atomistic level of a variety of processes of interest in physics, materials science, chemistry and biology. For instance, MD simulations are extensively used to study the dynamics and interactions of proteins, understand the properties of solutions or investigate transport in and on solids. From a technological point of view, molecular dynamics simulations play an important role in many fields such as drug development, the discovery of new materials, oil extraction or energy production. Indeed, enormous amounts of data are produced every day by molecular dynamics simulations running on high performance computers around the world and one of the big challenges related to such simulations is to make sense of the data and obtain mechanistic understanding in terms of low-dimensional models that capture the crucial features of the processes under study. Another central challenge is related to the time scale problem often affecting molecular dynamics simulations. More specifically, despite the exponential increase in computing power witnessed during the last decades and the development of efficient molecular dynamics algorithms, many processes are characterized by typical time scales that are still far beyond the reach of current computational capabilities. The central goal of this workshop was to discuss computational approaches capable of addressing such time scale problems in complex systems in materials science and biophysics. Another important goal of the workshop was to debate about how to facilitate the use of simulation and modelling in industrial settings. The program of the workshop included 17 talks, two round table discussions as well as one poster session. Discussions continued at the social dinners.

Specific information on the workshop

One of the goals of the workshop was to reinforce interactions between the academic and industrial research communities. Several scientists from non-academic research centers participated in the workshop and shared their experience:

- T. Trnka, Software for Chemistry & Materials, Amsterdam, The Netherlands

- M.G. Mota, Simune Atomistic Simulations, San Sebastian, Spain

- A. Pan, D.E. Shaw Research, New York, USA

- Tim Conrad, Modal AG, Berlin, Germany

The workshop was also attended by numerous doctoral students and postdocs, who mostly presented posters and greatly benefitted from interactions with the other workshop participants:

A. Arjun, University of Amsterdam,The Netherlands
Grisell Diaz Leines, Ruhr-Universität Bochum, Germany
Gyorgy Hantal, University of Vienna, Austria
Max Innerbichler, University of Vienna, Austria
Pavel Janoš, Masaryk University, Faculty of Science, Brno, Czech Republic
Miroslav Jurasek, Masaryk University, Faculty of Science, Brno, Czech Republic
Christian Leitold, UC Santa Barbara, USA
Emanuele Locatelli, University of Vienna, Austria
Laura Lupi, Faculty of Physics, University of Vienna, Austria
Wenping Lyu, RWTH Aachen, Germany
Donal MacKernan, University College Dublin, Irland
Marcin Minkowski, University of Vienna, Austria
Clemens Moritz, University of Vienna, Austria
Alberto Perez de Alba Ortíz, University of Amsterdam, The Netherlands
Lin Qin, Technical University of Vienna, Austria
Marcello Sega, Helmholtz-Institut Erlangen-Nürnberg, Germany
Huzaifa Shabbir, University of Vienna, Austria
Mateusz Sikora, MPI for Biophysics, Germany
Andreas Singraber, University of Vienna, Austria
Pavel Šmak, Masaryk University, Czech Republic
Andreas Troester, University of Vienna, Austria

Outcomes and achievements

Scientific discussions at the workshop centred around three fundamental computational challenges closely related to the time scale problem of classical MD simulation:

1. The calculation of the populations of metastable states of an equilibrium system. Such populations can be expressed in terms of free energies and hence this problem boils down to the efficient calculation of free energies. Sampling methods for such free energy calculations were discussed in several talks at the workshop.

2. The sampling of transition pathways between long-lived (meta)stable states and the calculation of reaction rate constants. Here the problem consists in sampling dynamical trajectories which can be very long for complex systems. Several talks discussed this problem and showed how path-based approaches can be used to study, for instance, the nucleation of gas hydrates, the crystallization of metals or the unbinding of a ligand from a protein. Simulations of such processes are facilitated by new scientific software tools, such as the Open Path Sampling (OPS) package, which provide flexible frameworks that can be easily extended and provide the tools required to handle large and complex systems.

3. The extraction of useful mechanistic information from the simulation data and the construction of low-dimensional models that capture the essential features of the process under study. Such models serve as the basis for the definition of reaction coordinates that enable in-depth studies of the process at hand. It has become evident during the workshop that new machine learning approaches have a huge potential for making progress on this very important problem. A number of talks discussed how to use supervised and unsupervised learning methods to identify collective variables that can be used to characterize complex molecular rearrangement.What has become clear in the talks and discussions during the workshop is that the key point in the application of machine learning methods to molecular simulations lies in the appropriate definition of descriptors on which the learning process is based. For instance, artificial neural networks have been shown to be able to provide very accurate and efficient representations of potential energy surfaces. A condition for the application of this approach, however, is that a set of molecular fingerprints is defined that contains sufficient information on molecular arrangements to make the energy prediction possible. The smart selection of descriptors is crucial in other machine learning approaches as well and it can be viewed as the interface between physics and chemistry and the world of machine learning.

The various themes discussed in the talks were picked up in two open discussion sessions on the first and second day of the workshop. The first discussion revolved on efficient path sampling methods and the identification of reaction coordinates. In particular, it was discussed how machine learning approaches can be used to make progress in this area and how extreme scale computational resources can be used efficiently to address these questions. Discussions on machine learning continued also in the second discussion, in which interactions between academia and industry was the other important topic. The workshop participants with industrial experience emphasized the importance of detailed project management and, in particular, the need to have very clear agreements about intellectual property rights. Industrial participants to the workshop also pointed out that small companies that develop software solutions can help to bridge the gap between academic research and industry.

The workshop demonstrated clearly that in order to make progress a community needs openly available codes that can be easily adapted, extended and combined. Until a few years ago, the field of rare event simulation lacked such a code, but in the mean time this deficit has been closed by the Open Path Sampling (OPS) and the PyRETIS package. It is crucial that these packages, which implement a wide range of path based methods, are interfaced with programs to generate dynamical trajectories (such as Gromacs, Lammps or CP2k) and to calculate collective variables (such as Plumed). Similarly, an open source software package (n2p2) is now available for the representation of atomistic potential energy surfaces. It is critical for the atomistic and molecular simulation community that development of these codes continues and that

they are made ready for use on extreme scale computing infrastructure. The availability of well documented and easily applicable software packages are also a condition for successful collaborations of academic researchers with industry.

While it is unlikely that short term societal benefits follow from the workshop, in the long term, activities such our workshop can have an important societal impact in several distinct ways, for instance:

- Many processes of importance in the fields of materials science and drug design are determined by rare events. So a detailed molecular understanding of new materials or drugs relies on our ability to study rare events in large-scale computer simulations. The simulation algorithms discussed in this meeting are an important step in this direction. In fact, several talks and discussions at the meeting touched on topics of direct economic relevance for instance the binding and unbinding of ligands to and from proteins and the catalytic properties of disordered substrates.

- The meeting also had a strong emphasis on the development of scientific software, mainly for transition path sampling and machine learning. Such software projects can have a huge impact on the research field and, in particular, on possible collaborations with industry.

- Early stage researchers working on the scientific software developments discussed in the workshop will have interesting job opportunities and will facilitate the transfer of knowledge from academic research to industry.

List of talks

Ben Leimkuhler	Advanced algorithms for sampling problems in chemistry and statistics
Bettina Keller	Girsanov reweighting for path ensembles and Markov state models
Michele Ceriotti	Atomic-structure representations between supervised and unsupervised learning
Mónica García Mota	SIMUNE and SIESTA-PRO: Professional atomistic simulation software ready for industry
Pratyush Tiwary	Three birds with one stone: reaction coordinate, free energies and kinetics in biomolecules with rare events
Gerhard Hummer	Can machine learning make rare events more frequent?
Andreas Singraber	High-dimensional neural network potentials in action: large-scale simulations of water and ice
Christine Peter	Dimensionality reduction aides scale-bridging in multi-resolution simulations of conformational landscapes
Tim Conrad	Modelling, Simulation and Data Analysis in an Industrial Context
John Chodera	Rare events and large-scale conformational changes in drug discovery
David Swenson	Path sampling of medically relevant biomolecular systems: New and old tricks using OpenPathSampling
Albert Pan	Atomic-level characterization of protein-protein association
Baron Peters	Isolated catalyst sites on amorphous supports: a wild frontier for ab initio calculations
Jutta Rogal	Reaction coordinate analysis for nucleation in metals
Titus van Erp	Path sampling and machine learning to identify reaction triggers
Fabio Pietrucci	Wide-spectrum collective variables for condensed matter transformations and efficient enhanced sampling schemes
Peter Bolhuis	At the limits of path sampling: protein dissociation and gas hydrate nucleation

Invited scientists

Peter Bolhuis, Michele Ceriotti, Selvaraj Chandrabose, John Chodera, Tim Conrad, Christoph Dellago, Grises Diaz Leines, Ralf Everaers, Monica Garcia Mota, György Hantal, Gerhard Hummer, Max Innerbichler, Pavel Janoš, Gerhard Kahl, Bettina Keller, Benedict Leimkuhler, Christian Leitold, Emanuele Locatelli, Laura Lupi, Wenping Lyu, Donal Mackernan, Marcin Mínkowski, Clemens Moritz, Ignacio Pagonabarraga, Albert Pan, Alberto Perez de Alba, Christine Peter, Baron Peters, Fabio Pietrucci, Lin Qin, Jutta Rogal, Huzaifa Shabbir, Mateusz Sikora, Andreas Singraber, Pavel Šmak, David Swenson, Pratyush Tiwary, Tomas Trnka, Andreas Tröster, Titus van Erp, Arjun Wadhawan.

Advances in Chemical Reaction Network Theory

Organizers: Gheorghe Craciun (U Wisconsin-Madison), Elisenda Feliu (U Copenhagen), Josef Hofbauer (U Vienna), Stefan Müller (U Vienna)

Dates: October 15 – 19, 2018

Budget: ESI € 13 040,
FWF, project 28406: € 238,
University of Vienna, Faculty of Mathematics: € 62.

Report on the workshop

The workshop brought together researchers from a wide range of mathematical disciplines (including differential equations and control theory, stochastic processes, algebraic geometry, and optimization) to discuss recent advances and to address open problems in chemical reaction network theory (CRNT). The workshop also reached out to neighboring areas such as singular perturbation theory and applied fields such as metabolic pathway analysis. Topics included long-term dynamical behaviour of reaction networks, continuous-state deterministic versus discrete-state stochastic modeling, and applications to metabolic networks.

Activities

The workshop started with the keynote lecture *What is special about autocatalysis?* by Peter Schuster. On Monday and Tuesday, there were five joint overview talks (given by two speakers each) on *Deterministic modeling – algebraic aspects*, *Deterministic modeling – dynamical aspects*, *Stochastic modeling*, *Singular perturbations*, and *Models of metabolism*. On Monday afternoon, every participant gave a mini talk (4 minutes) about their research interests and possible topics for discussion at the workshop.

The small number of overview talks and the mini talks by every participant allowed and stimulated discussions in self-organized workgroups. In a plenary session on Wednesday, topics for discussion were suggested, and, after a vote, five workgroups were formed. The discussions took place from Wednesday to Friday. For each work group, a speaker reported on progress (on Wednesday and Thursday afternoon). In a final plenary session on Friday, ideas were collected on how to increase the visibility of the CRNT community.

Specific information on the workshop

Among the fourty participants, there was an excellent group of young PostDocs (Martin Helmer, Jinsu Kim, Chuang Xu) and PhD students (Michael Adamer, Amir Hossein Sadeghi Manesh, Tung Nguyen, Nicola Vassena, Polly Yu), thanks to the support from ESI and their home institutions. The five overview talks were especially useful for the young researchers, and every PostDoc/PhD student had the opportunity to present their research in a mini talk.

Outcomes and achievements

The overview talks and the mini talks by every participant provided the basis for group work on five topics.

Workgroup 'Hopf bifurcations in models of phosphorylation cycles'
(proposed by Elisenda Feliu)

The group tried to determine whether a certain well-known phosphorylation cycle admits Hopf bifurcations and therefore oscillations. After the problem definition and a brainstorming, the network was compared to other networks for which the existence of Hopf bifurcations is known. Then the group of researchers with backgrounds ranging from computer algebra and analysis to singular perturbation theory split into small subgroups and discussed different strategies in detail. Progress was made by all subgroups, and partial results were obtained, but it remained open whether the cycle admits oscillations.

Workgroup 'Stationary distribution for an autocatalytic cycle'
(proposed by Enrico Bibbona)

The group tried to find an explicit form for the stationary distribution of the following reaction network: $2B \leftarrow A + B \rightarrow 2A, A \leftrightarrows 0 \leftrightarrows B$. No general theorem of CRNT applies, and simulations suggest that the network does not allow a stationary distribution in product form. However, the group immediately realized that a certain Lyapunov function guarantees that a stationary distribution exists and that all its moments are finite. The master equation could be written in a way that allows an iterative solution, however, as a function of a parameter. More work is needed to find a closed form solution. During the discussion, the question arose whether a single Lyapunov function (in the stochastic setting) allows to prove stability for all mass-action systems that are stable in the deterministic setting. The answer turned out to be no. Finally, the group studied specific conditions for Lyapunov functions, in particular, their limits at the boundary/at infinity.

Workgroup 'From ODEs to reaction networks with good properties'
(proposed by János Tóth)

The group started to work on the following inverse problem: How can one characterize ODEs arising from reversible and complex-balanced reactions (assuming mass-action kinetics)? The first results suggest that one can identify certain classes of equations induced by reversible reactions, and an algorithm can be given to find the inducing reversible reactions in the general case if such a realization exists. One can also decide if a given matrix contains the necessary complex vectors to induce an ODE.

Workgroup 'Sign vectors and tropical geometry'
(proposed by Andreas Weber)

Stoichiometry and thermodynamics impose constraints on the steady-state reaction rates (fluxes) in terms of sign vector conditions. The group discussed how to use sign vectors of fluxes in models of chemical reaction networks that have been simplified with the help of tropical geometry, in particular, how to improve solutions of the steady-state concentrations. The most promising route is to generate candidate solutions by tropical methods and to check them for stoichiometric and thermodynamic feasibility.

Workgroup 'Chordal ideals and reaction networks'
(proposed by Martin Helmer)

The group discussed the paper *Chordal Networks of Polynomial Ideals* (2017) by Cifuentes and Parrilo and its potential applications to chemical reaction networks. The focus was on understanding the computational aspects of chordal completion and what happens when an ideal is chordal. The group started to investigate which reaction networks might be naturally chordal and how the graph associated to the steady-state ideal of a network (as defined in the paper) is related to the species-reaction graph.

In the final plenary session, the participants discussed how to increase the visibility of the CRNT community. The following activities were suggested: tutorials in CRNT at (systems biology) summer schools, presentations of existing community software at COMBINE workshops, publication of an overview/perspective paper (for systems biologists), definition of benchmark/"model" problems, use of CRNT results in model selection/hypothesis generation.

List of talks

Peter Schuster	Keynote lecture: What is special about autocatalysis?
Elisenda Feliu & Carsten Wiuf	Overview talk: Deterministic models – algebraic aspects
Balázs Boros & Casian Pantea	Overview talk: Deterministic models – dynamical aspects
David Anderson & Daniele Cappelletti	Overview talk: Stochastic models
Peter Szmolyan & Sebastian Walcher	Overview talk: Singular perturbations
Stefan Müller & Georg Regensburger	Overview talk: Models of metabolism

Publications and preprints contributed

B. Boros, J. Hofbauer, S. Müller, G. Regensburger, *Planar S-systems: Global stability and the center problem*, Discrete and Continuous Dynamical Systems – Series A, 39(2): 707–727, 2019, https://doi.org/10.3934/dcds.2019029.

Yongjun Li, Valery Romanovski, *Hopf Bifurcations in a Predator-Prey Model with an Omnivore*, Submitted, 2018.

Invited scientists

Michael Adamer, Andrea Agazzi, David Anderson, Enrico Bibbona, Balázs Boros, Daniele Cappelletti, Carsten Conradi, George Craciun, Elisenda Feliu, Christoph Flamm, Martin Helmer, Josef Hofbauer, Matthew Johnston, Badal Joshi, Jinsu Kim, Markus Köbis, Ilona Kosiuk, Wolfram Liebermeister, Maya Mincheva, Stefan Mueller, Tung Nguyen, Diego Oyarzún, Casian Pantea, Matteo Polettini, Stefan Portisch, Georg Regensburger, Alan Rendall, Valery Romanovski, Amirhossein Sadeghi Manesh, Jan H. Van Schuppen, Peter Schuster, Gábor Szederkényi, Peter Szmolyan, Elisa Tonello, János Tóth, Nicola Vassena, Sebastian Walcher, Andreas Weber, Carsten Wiuf, Chuang Xu, Polly Yu, Jürgen Zanghellini.

ESI Symposium: Concepts of Probability in the Sciences

Organizers: Christoph Dellago (ESI, U Vienna), Wolfgang Reiter (ESI, U Vienna), Jakob Yngvason (ESI, U Vienna)

Dates: October 29 – 30, 2018

Budget: ESI Association € 10 480

Report on the symposium

This two day symposium was conceived as a survey of the many facets of probability and exemplary applications of probabilistic reasoning in the natural sciences. The speakers were experts coming from various disciplines while the target audience were interested researchers and students from the local community, in particular in physics, mathematics and the life sciences, who use probabilistic concepts regularly in their work but often without giving much thought to foundational issues.

The symposium was a cooperative project of the Association "Erwin Schrödinger International Institute for Mathematical Physics" and the Research Center ESI. The Association covered the direct costs of the event while the Research Center provided the organizational infrastructure.

Activities

The Symposium started with an introductory lecture on the probability concept from a historical perspective, presented by *Jos Uffink*, University of Minnesota. It was followed by 13 talks on different aspects of the subject. Ample time was reserved for discussions after each talk.

Sylvia Wenmackers, KU Leuven, talked about Conceptual Spaces and their use in shedding light on paradoxes in probability theory, and *Charlotte Werndl*, Salzburg about calibration and confirmation of probabilistic statements in climate science. *Sandy Zabel*, Northwestern University, reviewed the tension between subjective and the objective interpretations of probability. Various aspects of Statistical Physics and Thermodynamics were discussed in the talks of *Udo Seiefert*, Stuttgart, *Elliott Lieb*, Princeton, *Stefan Thurner*, Vienna, *Jean Bricmont*, Louvain, and *Gerhard Hummer*, Frankfurt. Randomness and probability in quantum physics were the subject of the presentations of *Rüdiger Schack*, London, *Časlav Brukner*, Vienna, and *Alexia Auffèves*, Grenoble. *Erik Curiel*, Munich, talked about mathematical challenges facing probabilistic reasoning in cosmology, and *Peter Schuster*, Vienna, about chance and randomness in molecular evolutionary processes.

List of talks

Jos Uffink	The Interpretation of Probability in a Historical Perspective
Sylvia Wenmackers	(P)paradox=100%
Sandy Zabell	The Subjective and the and Objective
Charlotte Werndl	Calibration and Confirmation in Climate Science
Rüdiger Schack	QBism and Normative Probability in Quantum Mechanics
Udo Seifert	Beyond the Second Law: Probability in Stochastic Thermodynamics
Elliott H. Lieb	Understanding Entropy without Probability
Časlav Brukner	Wigner's friend as a rational agent
Alexia Auffèves	What is Quantum in Quantum Randomness?
Jean Bricmont	Probabilistic Explanations and the Derivation of Macroscopic Laws
Erik Curiel	What Is Generic and What Is Special about the Universe?
Stefan Thurner	Where do all these Distribution Functions come from?

Gerhard Hummer   Inferring Statistical Ensembles from Experiment and Simulation
Peter Schuster   Chance and Randomness in Evolutionary Processes

Abstracts as well as slides of most of the talks can be found on the website `https://www.esi.ac.at/activities/events/2018/probability-symposium`, and video recording on ESI YouTube Channel `https://www.youtube.com/channel/UCUHyfvOFOuaUumnWaVrtfaQ/videos`.

Analysis and CR Geometry

Organizers: Shif Berhanu (Temple U), Anne-Katrin Gallagher (Oklahoma State U), Bernhard Lamel (U Vienna), Takeo Ohsawa (Nagoya U)

Dates: December 10 – 14, 2018

Budget: ESI € 9 600,
Third party funds from NPRP: € 3 869.

Report on the workshop

We aimed for our workshop "Analysis and Cauchy-Riemann Geometry" at the ESI to focus on advancing the historically rich and profitable interactions between the fields of integrable systems of partial differential equations (PDE) and several complex variables (SCV). In order to facilitate this goal, we invited a range of researchers from these areas which represented a broad range of these two fields.

The workshop, which was held in the beginning of December 2018, is considered a resounding success by the attending researchers and we think that the numerous exchanges facilitated within the workshop will reverberate throughout the represented fields for some time; we are overall happy with how it turned out.

Close to 50 researchers attended and participated in our workshop, about half of which were invited to give a talk. The talks represented cutting-edge research from several complex variables, integrable systems of PDEs, CR geometry, and complex geometry as well as talks allowing for historical reflection of how the fields (and their interactions) developed. We think that this gave a very interesting perspective, especially for the younger people attending.

In terms of several complex variables, the workshop offered important insights into a number of distinct areas of current research. One of the leading themes of research in this area is (and was for some while) the theory of the $\bar{\partial}$-Neumann problem and its ramifications, often referred to as the "L^2-theory" of the $\bar{\partial}$-complex. Often research in that area focuses on regularity properties of solutions to the (inhomogeneous) $\bar{\partial}$ equations, their relation to suitable convexity properties, and to the spectral properties of the encountered natural operators. The deep relations between several complex variables and CR geometry become apparent in research associated to these topics; and many such issues were visible in the workshop. In particular, the use of the inhomogeneous $\bar{\partial}$-equations to study problems associated to Levi-flat manifolds was important in several talks, as was the use of the L^2-theory for studying singularities of complex spaces.

In regard to CR geometry, as already pointed out previously, there is a great connection (to the field of several complex variables) due to its importance in the study of convexity properties. In our workshop, it was interesting to see that more research is being devoted to study very regular

(strictly pseudoconvex) settings again, even in low-dimensional settings (such as hypersurfaces in $\mathbb{C}^2$). This can be attributed to the better understanding of some of the underlying problems of low-dimensional CR geometry: It turns out that it is essential to understand the role of non-integrable structures there. Another interesting development in the field is the resurgence of research into CR structures with some symmetry properties.

The structures encountered in CR geometry are particular examples of integrable structures, and we were happy to have some experts of that area present at the workshop. Integrable structures and several complex variables also have a natural contact point in the use of microlocal techniques, many of whose special properties are shared by the two fields. In particular, some recent results on geometrical conditions ensuring solvability of the complex associated to the partial differential operator which takes the role of the $\bar{\partial}_b$-operator in several complex variables were discussed; these have further applications in terms of hypoellipticity of partial differential operators.

Activities

The workshop featured 17 "long" (= 50 minutes excluding discussion) and 9 "short" (= 30 minutes excluding discussion) talks. The long talks were mostly given by senior researchers, while the short talks were mostly given by more junior people – the logic behind this decision was that longer talks usually aimed to present a broader view of the subject, while the shorter talks focused on presenting recent results.

The activities were organized in a manner creating a "light" schedule which left ample time to use the ESI's excellent facilities for collaboration and informal meetings (some of which were announced to a broader audience, depending on their nature). We think that this is a rather successful approach; while many workshops have a tight schedule, including structured networking events and such, we feel that a light schedule leaves space to continue a discussion started after a talk as well as meeting with collaborators to discuss avenues of attack to a common problem. The workshop participants have commented overall positively on this approach.

Additionally, we offered the junior participants, pre- and postdocs, to represent their research projects and work in a poster session. However, there was not enough interest to actually generate one; the general feedback was that the junior people preferred to have time to either pursue collaborations or present their work to interested senior people in a more informal setting. Judging from walking by the various blackboard discussion, this seems to have worked out in everybody's favour.

We organized one social highlight, an excursion to a typical Austrian "Heurigen" in Klosterneuburg, overlooking the local monastery and the city. Our foreign visitors enjoyed this authentic Austrian experience a lot.

Specific information on the workshop

Overall, **15 young researchers** at different stages of their careers participated in the workshop; a (P) designates a predoc: Severine Biard, Gregorio Chinni, Stefan Fürdös, Sean Curry, Luke Edholm, Purvi Gupta, Tobias Harz, Jimmy Johansson (P), Yuta Kusakabe (P) , Octavian Mitrea (P), Sofia Ortega Castillo, Martin Sera, Weixia Zhu (P), Thomas Pawlaschyk, Michael Brünnig (P).

We have actually offered special (competitively awarded) pre- and post-doc stipends for attending the workshop, covering local (and sometimes also travel) expenses. This offer was taken

up enthusiastically in the community, and we actually had to slightly extend the budget for this programme in order to accommodate the many excellent applications.

Thus, predoctoral researchers mostly came at their own will. Those which were rather far advanced in their doctoral studies and about to enter the job market were invited to present their work; those which were still at the research stages of their degree work were basically participating in the workshop, and so had the chance to meet and interact with some of the leaders of the field.

The (non-local) postdoctoral researchers participating at the workshop were all given the opportunity to give a (mostly short) talk, and thus were able to present their current work to a larger audience.

Outcomes and achievements

Sonmez Sahutoglu, Gian Maria Dall'ara, Debraj Chakrabarti started collaborating on a project on restriction operators.

Friedrich Haslinger, John D'Angelo started collaborating on a project concerning the representation of Hermitian forms as sums of squares.

Paulo Cordaro, Giuseppe Della Sala, and Bernhard Lamel finished a preprint "The Borel map for compact subsets in the plane" which has been submitted for publication (and thank the ESI).

Florian Bertrand, Giuseppe Della Sala, and Bernhard Lamel worked on the paper "Extremal discs and Segre varieties for real-analytic hypersurfaces in $\mathbb{C}^2$".

List of talks

Bernhard Lamel	Some aspects of the work of Friedrich Haslinger
Siqi Fu	Aspects of Emil J. Straube's work on the $\bar{\partial}$-Neumann problem
Purvi Gupta	Convexity properties of even-dimensional compact manifolds
Judith Brinkschulte	On Levi-flat CR manifolds, positive line bundles and extension problems
Severine Biard	Weighted L^2 polynomial approximation in $\mathbb{C}$
Laurent Stolovitch	Linearizations of neighborhoods of embeddings of complex compact manifolds
Nikolay Shcherbina	On core and hyperbolicity of some model domains
Jeffery McNeal	Irregularity of Bergman projections and consequences
Luke Edholm	Sub-Bergman projections: Duality and Approximation
Jean Ruppenthal	Chern forms of singular metrics on vector bundles
Martin Sera	Wedge Products of closed positive currents with analytic singularities and its application
Nordine Mir	Convergence and Divergence of formal CR mappings
Chin-Yu Hsiao	*G*-equivariant embedding theorems for CR manifolds of high dimension
Ilya Kossovskiy	Real-analytic coordinates for smooth CR-hypersurfaces
Yunus Zeytuncu	Spectra of Kohn Laplacians on CR manifolds
John D'Angelo	Rational Spere Maps
Peter Ebenfelt	Bounded strictly pseudoconvex domains in $\mathbb{C}^2$ with obstruction flat boundary
Sean Curry	CR manifolds with an essential symmetry
Giuseppe Della Sala	A characterization of sphericity by analytic discs
Paulo D. Cordaro	Semi-local analytic solvability in differential complexes associated to locally integrable structures
Jorge G. Hounie	Global solvability of real analytic involutive systems on compact manifolds, Part 2
Christine Laurent-Thiebaut	Characterizing density properties by mean of Dolbeault cohomology

Jiri Lebl   Levi-flat Plateau problem
Masanori Adachi   Ampleness of positive CV line bundles over Levi-flat manifolds, revisited
Florian Bertrand   Stationary discs and jet determination for non-degenerate real submanifolds
Franc Forstneric   H-principle for complex contact structures on Stein manifolds

Publications and preprints contributed

Franc Forstneric, *H-principle for complex contact structures on Stein manifolds*, arxiv.org/abs/1810.12943, [math.CV].

Sofia Ortega Castillo, *Strong pseudoconvexity in Banach spaces*, in preparation.

Luke D. Edholm, Jeffery D. McNea, *Sobolev mapping of some holomorphic projections*, arXiv:1904.04383, [math.CV].

Mehmet Celik, Sonmez Sahutoglu, Emil Straube, *Convex Domains, Hankel Operators, and Maximal Estimates*, arxiv:1902.10316, [math.CV].

Invited scientists

Masanori Adachi, Takao Akahori, Shiferaw Berhanu, Severine Biard, Judith Brinkschulte, Michael Brünnig, Gregorio Chinni, Paolo Cordaro, Sean Curry, John D'Angelo, Giuseppe Della Sala, Peter Ebenfelt, Luke Edholm, John Erik Fornaess, Franc Forstneric, Siqi Fu, Stefan Fürdös, Anne-Kathrin Gallagher, Purvi Gupta, Tobias Harz, Friedrich Haslinger, Jorge G. Hounie, Chin-Yu Hsiao, Jimmy Johansson, Yuta Kusakabe, Bernhard Lamel, Christine Laurent-Thiebout, Jiri Lebl, Kazuko Matsumoto, Jeff McNeal, Francine Meylan, Nordine Mir, Octavian Mitrea, Stephanie Nivoche, Takeo Ohsawa, Sofia Ortega Castillo, Thomas Pawlaschyk, Jean Ruppenthal, Sonmez Sahutoglu, Gerd Schmalz, Martin Sera, Rausl Shafikov, Nikolay Shcherbina, Laurent Stolovitch, Emil Straube, Atsushi Yamamori, Yunus E. Zeytuncu, Weixia Zhu.

Research in Teams

Research in Teams Project 1: Traveling Waves in Hydrodynamics

Collaborators: Armengol Gasull (U Autonoma de Barcelona), Anna Geyer (Delft U of Technology), Víctor Mañosa (U Politecnica de Catalunya)

Dates: July 1 – 31, 2018

Budget: ESI € 6 240

Report on the project

Scientific Background

More than 250 years ago, Leonard Euler derived the equations of hydrodynamics and still they present a great challenge to the scientific community: even in the simplest non-trivial setting of physical relevance the exact governing equations are almost intractable, Gerstner's waves being the only known explicit solutions. An approach that proved very successful was the derivation of simplified model equations which arise as accurate approximations of Euler's equations in certain physical regimes. A number of models have been proposed for shallow water waves in irrotational flows, as for instance the well-known Korteweg-de Vries (KdV) equation, the Camassa-Holm (CH) equation and the corresponding equation for the free surface, and more recently a highly nonlinear equation modeling large amplitude waves [Q, GQ].

Traveling wave solutions of the aforementioned equations and other related equations have been studied extensively in recent years. For most equations explicit solutions are not known and obtaining solutions in closed form is usually out of reach due to the high degree of non-linearities. Therefore, obtaining a thorough qualitative understanding of solutions is of utmost importance. Different approaches have been employed to obtain a deeper understanding of the existence and stability of traveling wave solutions, such as variational techniques as well as methods from dynamical systems. In the current project we aim to extend those methods and develop new techniques to prove existence of different types of traveling wave solutions.

Project aims and scope

This project is focused on traveling wave solutions for nonlinear dispersive equations modeling shallow water waves as described above. Our main objective is two-fold: our first aim is the characterization of smooth and singular solutions of these equations using methods from dynamical systems and qualitative ODE theory. Secondly, we are interested in periodic solutions for nonlinear dispersive PDE with perturbation terms. To make headway we had to develop new methods and find suitable adaptations of known results which we specify below.

Outcomes and achievements

During the first part of our stay we focused on the study of a family of systems of PDE introduced in [EHKL]. In this work, a family of two-component systems of nonlinear equations which model two-dimensional shallow water waves with constant vorticity was derived, which

includes a generalization of the celebrated Camassa–Holm equation. We analysed the associated systems of ODE for traveling waves and found that it exhibits qualitative features compatible with the existence of singular traveling waves (in particular cusped ones), cf. [GG, GeM]. It turns out, however, that any such singular solution fails to be in the space $H^1_{\mathrm{loc}}(\mathbb{R})$ and would therefore not satisfy an appropriate weak formulation of the equation. As a consequence, we were able to prove that for these systems only regular traveling wave solutions can exist. Our results are, in fact, in good agreement with the ones obtained in [DI] and [M].

During the second part of our stay we developed a new technique to prove the existence of periodic traveling wave solutions for a large class of nonlinear dispersive PDE with perturbation terms. This technique is obtained by adapting and combining methods of averaging theory, the use of Melnikov functions associated to perturbed Hamiltonian systems, and the classical theory of Abelian integrals, see [CL] or [UM] for instance. It allows us to prove existence of periodic traveling waves by identifying isolated periodic solutions of perturbed Hamiltonian systems. Using this technique we have succeed to prove the existence of periodic traveling wave solutions for a large class of perturbed nonlinear dispersive PDE, including CH, KdV, Boussinesq equation, Klein-Gordon equation, and the Ostrovsky equation. We have also adapted the technique to prove the persistence of fronts in perturbations of the Fisher-Kolmogorov equations and others. A manuscript including a detailed description and proof of these results is in preparation, see [GGM1].

Our approach strongly relies on the development of tools for detecting isolated periodic solutions for ODE systems and homoclinic or heteroclinic connections, which give rise to different types of traveling wave solutions. For this reason, part of our research has focused on the development of such tools and methods to prove the existence of this type of solutions. In particular, we have worked on the following two further projects:

A. Gasull and V. Mañosa have developed a new technique to demonstrate the existence of periodic solutions using the Poincaré-Miranda Theorem. A preprint of this exciting result is now available, see [GaM].

A. Gasull and A. Geyer have worked on the development of criteria which allow to deduce Chebychev properties for certain families of Abelian integrals. These criteria can be applied to perturbations of periodic non-autonomous ODE to determine upper bounds for the number of isolated periodic solutions for certain systems of differential equations, for instance Hamiltonian systems with double potential or pendulum equations. This project is carried out in collaboration with F. Mañosas from the Dynamical Systems group at UAB. A manuscript is in preparation, see [GGM2].

Publications and preprints contributed

[GGM1]   A. Gasull, A. Geyer, V. Mañosa, *Periodic traveling waves for perturbed partial differential equations.* In preparation.

[GGM2]   A. Gasull, A. Geyer, F. Mañosas, *Chebyshev Criteria for Abelian integrals with applications to perturbations of periodic non-autonomous ODEs.* In preparation.

[GaM]   A. Gasull, V. Mañosa, *Periodic orbits of discrete and continuous dynamical systems via Poincaré-Miranda theorem.* arXiv:1809.06208 [math.DS] (2018)

References

[CH]   R. Camassa, D. D. Holm. *An integrable shallow water equation with peaked solitons.* Phys. Rev. Lett. 71 (1993) 1661–1664.

[CL]   C. Christopher, C. Li. Limit Cycles of Differential Equations. Advanced Courses in Mathematics - CRM Barcelona, Birkhäuser, Basel 2007.

[DI]   D. Dutykh, D. Ionescu-Kruse. *Travelling wave solutions for some two-component shallow water models.* J.Differential Equations 261 (2016) 1099–1114.

[EHKL] J. Escher, D. Henry, B. Kolev, T. Lyons. *Two-component equations modelling water waves with constant vorticity.* Annali di Matematica 195 (2016) 249–271.

[GG]   A. Gasull, A. Geyer, *Traveling surface waves of moderate amplitude in shallow water.* Nonlinear Anal. Theory, Methods Appl. 102 (2014) 105–119.

[GeM]   A. Geyer, V. Mañosa, *Singular solutions for a class of traveling wave equations.* Nonlinear Anal. Real World Appl. 31 (2016) 57–76.

[GQ]   A. Geyer, R. Quirchmayr. *Traveling wave solutions of a highly nonlinear shallow water equation.* Discret. Contin. Dyn. Syst. Ser. A. 38 (2018) 1567–1604.

[GN]   A. Green, P. Naghdi. *A derivation of equations for wave propagation in water of variable depth*, J. Fluid Mech. 78 (1976) 237–246.

[M]   K. Mohajer. *A Note on traveling wave solutions to the two component Camassa-Holm Equation.* Journal of Nonlinear Mathematical Physics 16 (2009) 117–125.

[Q]   R. Quirchmayr. *A new highly nonlinear shallow water wave equation.* J. Evol. Equations. 16 (2016) 539–567.

[UM]   M. Uribe, H. Movasati, *Limit Cycles, Abelian Integral and Hilbert's Sixteenth Problem.* Publicações Matemáticas 31 Colóquio Brasileiro de Matemática, IMPA, Sao Paulo 2017.

Research in Teams Project 2: Finite Insoluble Subgroups of the Space Cremona Group

Collaborators: Hamid Ahmadinezhad (Loughborough U), Ivan Cheltsov (U of Edinburgh), Jihuan Park (Pohang U of Science and Technology), Konstantin Shramov (Steklov Institute, Moscow)

Dates: August 1 – 31, 2018

Budget: ESI € 8 320

Report on the project

The team project at ESI consists of three topics as follows:
– Automorphism groups of del Pezzo threefolds of degree 1.
– Birational geometry of weighted threefold hypersurfaces.
– K-stability of singular del Pezzo surfaces.

Scientific Background

Automorphism groups of del Pezzo threefolds of degree 1. A del Pezzo threefold is a Fano threefold X with terminal Gorenstein singularities such that $-K_X \sim 2H$ for some ample Weil divisor H; the number $d = H^3$ is usually referred to as the degree of X. It is well known that

$d \leq 8$. The most interesting varieties in this series are those with small d, namely with $d \leqslant 5$. For instance, del Pezzo threefolds with $d = 3$ are cubic hypersurfaces in $\mathbb{P}^4$, while those with $d = 2$ are quartic double solids. For each of these deformation families, it is interesting to figure out the maximal possible number of isolated singularities and study such varieties with the maximal number of singular points. Such varieties usually enjoy very nice birational properties and sometimes have large automorphism groups, providing their embeddings to the Cremona group. For instance, for $d = 3$ the del Pezzo threefold with the maximal possible number of singularities is unique; it is classically known as the Segre cubic. It has 10 nodes, and its automorphism group is the symmetric group $\mathfrak{S}_6$. For $d = 2$, the singular del Pezzo threefolds may allow 16 nodes to the fullest and such del Pezzo threefolds form a three-dimensional family. They are double solids branched over Kummer quartic surfaces, so that their automorphism groups can be studied in terms of the corresponding curves of genus 2.

It is known (see [Pro 13]) that for $d = 1$ the maximal number of singular points on a del Pezzo threefold is 28. Furthermore, all 28-nodal del Pezzo threefolds of degree 1 can be obtained as anticanonical models of blow ups of $\mathbb{P}^3$ of seven points in general position. However, such a construction is usually not equivariant with respect to the whole automorphism group of X.

Birational geometry of weighted threefold hypersurfaces. End points of Minimal Model Program are either Mori fibre spaces or Minimal models. In dimension three, Mori fibre spaces form three classes: Fano threefolds, del Pezzo fibrations over curves, and conic bundles over surfaces. Naturally, they are $\mathbb{Q}$-factorial with at worst terminal singularities, and with relative Picard number one. Such a Fano variety admits a minimal embedding into a weighted projective space via the plurianticanonical ring. There are finitely many deformation families of Fano threefolds, and studying birational relations among them, as well as birational maps to other Mori fibre spaces is much interesting, as it sheds light to birational classification of 3-folds.

Let X be a Fano threefold of Picard rank 1 and Fano index I with terminal $\mathbb{Q}$-factorial singularities. There are precisely 130 families of Fano 3-folds whose plurianticanonical ring define an embedding as a hypersurface into weighted projective space. In these case, the $\mathbb{Z}$-graded ring $R(X,H) = \bigoplus_{m \geqslant 0} H^0\left(X, -mH\right)$ has 5 generators, say x, y, z, t, w, respectively in degrees a_0, a_1, a_2, a_3, a_4, with one algebraic relation amongst them. This redefines X as a (weighted) hypersurface in $\mathbb{P}(a_0, a_1, a_2, a_3, a_4)$ of degree $d = \sum_{i=0}^4 a_i - I$.

Of these 130 families, exactly 95 have index one and their geometry is well-studied:

Theorem 1 ([CP17]) If $I = 1$ and X is quasi-smooth, then X is birationally rigid.

***K*-stability of singular del Pezzo surfaces.** Let S_d be a quasismooth and well-formed hypersurface in $\mathbb{P}(a_0, a_1, a_2, a_3)$ of degree d, where $a_0 \leqslant a_1 \leqslant a_2 \leqslant a_4$. Let $I = a_0 + a_1 + a_2 + a_3 - d$ and suppose that I is positive. Then S_d is a del Pezzo surfaces with at most quotient singularities.

For $I = 1$, Johnson and Kollár produced the (infinite) list of all possibilities for the quintuple (a_0, a_1, a_2, a_3, d) in [JK01]. They also proved the following result:

Theorem 2 ([JK01, Theorem 8]) Suppose that S_d with $I = 1$ is singular and the quintuple (a_0, a_1, a_2, a_3, d) is not one of the following four quintuples:

$$(1,2,3,5,10), (1,3,5,7,15), (1,3,5,8,16), (2,3,5,9,18). \tag{1}$$

Then S_d admits an orbifold Kähler–Einstein metric.

Its proof uses the criterion given by the α-invariant of the surface S_d [T87]. It says that S_d admits an (orbifold) Kähler–Einstein metric if the inequality

$$\alpha(S_d) > \frac{2}{3} \tag{2}$$

holds, where $\alpha(S_d)$ is the α-invariant of the surface S_d. Indeed, Johnson and Kollár verified (2) in the case when $I = 1$, the surface S_d is singular, and the quintuple (a_0, a_1, a_2, a_3, d) is not one of the four exceptions (1). Two of the four remaining cases (1) have been treated in [A02] by Araujo, who proved the following result:

Theorem 5 ([A02, Theorem 4.1]) In the following two cases:
$(a_0, a_1, a_2, a_3, d) = (1, 2, 3, 5, 10)$,
$(a_0, a_1, a_2, a_3, d) = (1, 3, 5, 7, 15)$ and the equation of S_d contains yzt,
the inequality $\alpha(S_d) > \frac{2}{3}$ holds. In particular, S_d admits a Kähler–Einstein metric.

We have dealt with the other two cases of (1) in [CPS10]. To be precise, we proved the following result:

Theorem 6 ([CPS10, [Theorem 1.10]). Suppose that $(a_0, a_1, a_2, a_3, d) = (1, 3, 5, 8, 16)$ or $(2, 3, 5, 9, 18)$. Then $\alpha(S_d) > \frac{2}{3}$, so that S_d admits a Kähler–Einstein metric.

In [CPS10], we also intensively investigated the cases with $I \geqslant 2$. In fact, the problem of existence of an orbifold Kähler–Einstein metric on the surface S_d with $I \geqslant 2$ was first studied by Boyer, Galicki and Nakamaye in [BGN03]. They observed that the criterion (2) cannot be applied to S_d in the case when $I \geqslant \frac{3}{2} a_0$. Moreover, in the case when $2 \leqslant I < \frac{3}{2} a_0$, they found all possibilities for the quintuple (a_0, a_1, a_2, a_3, d). In [CS13, CPS10], we evaluated the α-invariants for most of the corresponding del Pezzo surfaces. This gave

Theorem 7 ([CS13, CPS10]). Suppose that (a_0, a_1, a_2, a_3, d) is one of the quintuples found in [BGN03]. Then $\alpha(S_d) > \frac{2}{3}$ except for the following six cases:

- $(a_0, a_1, a_2, a_3, d) = (7, 10, 15, 19, 45), (7, 18, 27, 37, 81), (7, 15, 19, 32, 64),$
  $(7, 19, 25, 41, 82), (7, 26, 39, 55, 117)$

- $(a_0, a_1, a_2, a_3, d) = (2, 3, 4, 5, 12)$ and equation of S_d does not contain yzt.

Project aims and scope

Automorphism groups of del Pezzo threefolds of degree 1. All 28-nodal del Pezzo threefolds of degree 1 can be obtained as anticanonical models of blow ups of $\mathbb{P}^3$ of seven points in general position. However, such a construction is usually not equivariant with respect to the whole automorphism group of X. It appears that there is a different construction more suitable for studying automorphism groups of threefolds.

Let X be a del Pezzo threefold of degree 1. Then the linear system $|-\frac{1}{2} K_X|$ defines a rational elliptic fibration $\phi \colon X \dashrightarrow \mathbb{P}^2$. Let Δ be the discriminant curve of ϕ, and $\check{\Delta} \subset \check{\mathbb{P}}^2$ be its projective dual. It turns out that the dual curve is a smooth plane quartic curve. The project investigates the described correspondence between the family of 28-nodal del Pezzo surfaces of degree 1 and the family of smooth plane quartics.

Birational geometry of weighted threefold hypersurfaces. Weighted Fano threefold hypersurfaces of index $I \geqslant 2$ are listed in the following table:

No.	$X_d \subset \mathbb{P}(a_0, a_2, a_2, a_3, a_4)$	I	No.	$X_d \subset \mathbb{P}(a_0, a_2, a_2, a_3, a_4)$	I
96	$X_3 \subset \mathbb{P}(1,1,1,1,1)$	2	114	$X_6 \subset \mathbb{P}(1,1,2,3,4)$	5
97	$X_4 \subset \mathbb{P}(1,1,1,1,2)$	2	115	$X_6 \subset \mathbb{P}(1,2,2,3,3)$	5
98	$X_6 \subset \mathbb{P}(1,1,1,2,3)$	2	116	$X_{10} \subset \mathbb{P}(1,2,3,4,5)$	5
99	$X_{10} \subset \mathbb{P}(1,1,2,3,5)$	2	117	$X_{15} \subset \mathbb{P}(1,3,4,5,7)$	5
100	$X_{18} \subset \mathbb{P}(1,2,3,5,9)$	2	118	$X_6 \subset \mathbb{P}(1,1,2,3,5)$	6
101	$X_{22} \subset \mathbb{P}(1,2,3,7,11)$	2	119	$X_6 \subset \mathbb{P}(1,2,2,3,5)$	7
102	$X_{26} \subset \mathbb{P}(1,2,5,7,13)$	2	120	$X_6 \subset \mathbb{P}(1,2,3,3,4)$	7
103	$X_{38} \subset \mathbb{P}(2,3,5,11,19)$	2	121	$X_8 \subset \mathbb{P}(1,2,3,4,5)$	7
104	$X_2 \subset \mathbb{P}(1,1,1,1,1)$	3	122	$X_{14} \subset \mathbb{P}(2,3,4,5,7)$	7
105	$X_3 \subset \mathbb{P}(1,1,1,1,2)$	3	123	$X_6 \subset \mathbb{P}(1,2,3,3,5)$	8
106	$X_4 \subset \mathbb{P}(1,1,1,2,2)$	3	124	$X_{10} \subset \mathbb{P}(1,2,3,5,7)$	8
107	$X_6 \subset \mathbb{P}(1,1,2,2,3)$	3	125	$X_{12} \subset \mathbb{P}(1,3,4,5,7)$	8
108	$X_{12} \subset \mathbb{P}(1,2,3,4,5)$	3	126	$X_6 \subset \mathbb{P}(1,2,3,4,5)$	9
109	$X_{15} \subset \mathbb{P}(1,2,3,5,7)$	3	127	$X_{12} \subset \mathbb{P}(2,3,4,5,7)$	9
110	$X_{21} \subset \mathbb{P}(1,3,5,7,8)$	3	128	$X_{12} \subset \mathbb{P}(1,4,5,6,7)$	11
111	$X_4 \subset \mathbb{P}(1,1,1,2,3)$	4	129	$X_{10} \subset \mathbb{P}(2,3,4,5,7)$	11
112	$X_6 \subset \mathbb{P}(1,1,2,3,3)$	4	130	$X_{12} \subset \mathbb{P}(3,4,5,6,7)$	13
113	$X_4 \subset \mathbb{P}(1,1,2,2,3)$	5			

The project is to check which Fano threefolds in these families are birationally rigid.

K-stability of singular del Pezzo surfaces. Recently Fujita and Odaka introduced a new invariant of Fano varieties, which they called δ-invariant, that serves as a strong criterion for uniform K-stability.

Theorem 8 ([FO18, BJ17]).
Let X be a Fano variety with at most Kawamata log terminal singularities. Then X is uniformly K-stable if and only if $\delta(X) > 1$.

This powerful tool has been practiced for smooth del Pezzo surfaces in [ParkWon,CZ], and therein its effectiveness has been presented. Around the same time, Li, Tian and Wang proved in [LTW17] that the result of Chen, Donaldson, Sun and Tian also holds for some singular Fano varieties. In particular, it holds for del Pezzo surfaces with quotient singularities. This gives

Theorem 9. If $\delta(S_d) > 1$, then S_d admits an (orbifold) Kähler–Einstein metric.

The project at ESI is to apply this theorem to all remaining cases in Theorem 7.

Outcomes and achievements

Automorphism groups of del Pezzo threefolds of degree 1. The project at ESI has produced the result as follows:

Theorem 10. If X a del Pezzo threefold of degree 1 with 28 nodes, then the corresponding dual curve $\check{\Delta}$ is a smooth plane quartic. Furthermore, the assignment $X \mapsto \check{\Delta}$ is a one-to-one correspondence between the family of 28-nodal del Pezzo surfaces of degree 1 and the family

of smooth plane quartics.

As a by-product of Theorem 10, we obtained the following result.

Corollary 11. Let X be a del Pezzo threefold of degree 1 with 28 nodes and let $\check{\Delta}$ be the corresponding plane quartic. Let Y be the double cover of $\check{\mathbb{P}}^2$ branched over $\check{\Delta}$. For a subgroup G of $\mathrm{Aut}(\check{\Delta})$, we have that $\mathrm{rk}\,\mathrm{Cl}(X)^G = \mathrm{rk}\,\mathrm{Pic}(Y)^G$.

Using Corollary 11, we can obtain several new examples of G-birationally rigid rational del Pezzo threefolds.

Example 12. Let X be the unique 28-nodal del Pezzo threefold of degree 1 with an action of the group $G \cong \mathrm{PSL}_2(\mathbf{F}_7)$. Then X is G-birationally super-rigid.

We are writing the paper [CPSH2019] about this.

Birational geometry of weighted threefold hypersurfaces. The project at ESI proved that, contrary to index one case, there are no birationally rigid Fano hypersurfaces with $I \geqslant 2$.

Theorem 13. Let X be a quasi-smooth member of Family No. n. Then
(a) there exists a birational map to a Mori fibration over a curve or a surface if
$n \in \{96, 97, 98, 99, 107, 108, 109, 116, 117, 122\}$,
(b) there exists at least one elementary Sarkisov link from X to another Fano 3-fold if $n \in \{100, 101, 102, 103, 110\}$,
(c) in the remaining cases, the threefold X is rational.

Theorem 13, together with [CP17] implies the following corollary.

Corollary 14. A quasi-smooth $\mathbb{Q}$-factorial Fano 3-fold hypersurface with terminal singularities is birationally rigid if and only if it has index one.

We are writing the paper [CPSH2018] about this.

***K*-stability of singular del Pezzo surfaces.** The project has yielded the following:

Theorem 15. Suppose that S_d is one of the six exceptional del Pezzo surfaces in Theorem 7. Then $\delta(S_d) \geqslant \frac{65}{64}$. In particular, the surface S_d admits a Kähler–Einstein metric.

We have written the paper [CPS2018] about this.

Publications and preprints contributed

[CPS2018]   I. Cheltsov, J. Park, C. Shramov, *Delta invariants of singular del Pezzo surfaces*, arXiv:1809.09221.

[CPSH2018]   I. Cheltsov, J. Park, C. Shramov, H. Ahmadinezhad, *On geometry of Fano 3-fold hypersurfaces*, in preparation.

[CPSH2019]   I. Cheltsov, J. Park, C. Shramov, H. Ahmadinezhad, *Double Veronese cones with* 28 *nodes*, in preparation.

References

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[BGN03]   C. Boyer, K. Galicki, M. Nakamaye, *On the geometry of Sasakian–Einstein* 5-*manifolds*, Math. Annalen **325** (2003), 485–524.

[CP17]   I. Cheltsov and J. Park, *Birationally rigid Fano threefold hypersurfaces*, Mem. Amer. Math. Soc. **246** (2017), no. 1167, v+117.

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[CDS15]   X.-X. Chen, S. Donaldson, S. Sun, *Kähler–Einstein metrics on Fano manifolds. I, II, III*, J. Amer. Math. Soc. **28** (2015), no. 1, 183–197, 199–234, 235–278.

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[JK01]   J. Johnson, J. Kollár, *Kähler–Einstein metrics on log del Pezzo surfaces in weighted projective* 3-*spaces*, Ann. de l'Institut Fourier **51** (2001), 69–79.

[LTW17]   C. Li, G. Tian, F. Wang, *On Yau–Tian–Donaldson conjecture for singular Fano varieties*, preprint, arXiv:1711.09530 (2017).

[PW18]   J. Park, J. Won, *K-stability of smooth del Pezzo surfaces*, to appear in Math. Ann.

[Pro13]   Yu. Prokhorov. *G-Fano threefolds, I.* Adv. Geom. **13** (2013), no. 3, 389–418.

[T87]   G. Tian, *On Kähler–Einstein metrics on certain Kähler manifolds with* $c_1(M) > 0$, Inv. Math. **89** (1987), 225–246.

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 by the Austrian Ministry of Education, Science and Culture and the U of Vienna. 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:

Lecture Courses, Winter Term 2017/18:

Eric Bergshoeff (U of Groningen):
Applied Newton-Cartan Geometry
Lecture Course (260053 VO): January 10 to 29, 2018
Wednesday, January 10, Friday, January 12, Friday January 19, Wednesday, January 24, Friday, January 26, Monday, January 29, 2018// Time: 9:15 - 10:45 a.m.

Lecture Courses, Summer Term 2018:

Francis Filbet (Université Paul Sabatier, Toulouse III & Institut Universitaire de France):
Introduction to Kinetic Theory: The Boltzmann Equation
Lecture Course (442504 VO): July 31 – August 3, 2018
Monday to Friday 9:30 – 11:00 and 11:45 – 12:30

Visitors associated with Senior Research Fellowships:

Ceyda Simsek (U of Groningen), January 3 – March 3, 2018

Fabio Riccioni (Università di Roma 'La Sapienza'), January 24 – January 27, 2018

Athanasios Chatzistavrakidis (Rudjer Bošković Institute, Zagreb, Croatia), February 5 – February 9, 2018

Eric Bergshoeff: Applied Newton-Cartan Geometry

Course

Einstein's General Relativity is considered to be one of the cornerstones of modern physics for the obvious reason that many phenomena, such as the bending of light by the sun and the recently observed merging of two black holes, can be described correctly using this theory. Despite this huge success on the part of General Relativity, recently the realization has dawned that non-relativistic gravity encapsulates much more than the standard Newton's law of gravity that can only be used to describe gravity with weak gravitational fields and at velocities that are low with respect to the speed of light. Different models of non-relativistic gravity have emerged that can be applied as novel tools to grasp properties of non-relativistic non-gravitational phenomena that are otherwise difficult to access. The most prominent among these models is Newton-Cartan (NC) gravity which is a formulation of Newtonian gravity in a frame-independent way, consistent with the principle of equivalence. It is based upon a geometry that differs from the Riemannian geometry describing the curvature of spacetime in General

Relativity. This geometry is called NC geometry and has the distinguishing feature that it has a so-called foliation that allows an absolute time direction that all observers agree upon.

In the first part of the course, after a historical introduction, I first reviewed some basic concepts of General Relativity, relevant for the remainder of the course, such as the Vierbein formalism and how to obtain the kinematics of General Relativity by applying a so-called gauging procedure to the Poincaré algebra of relativistic symmetries. I then showed that, in the non-relativistic case, it is not sufficient to work with the Galilei algebra as a contraction of the Poincaré algebra. Using the non-relativistic particle as an example I showed that one is forced to work with a central extension of the Galilei algebra, which is called the Bargmann algebra. Furthermore, I showed how the equations of motion of Newton-Cartan gravity can be obtained by applying a special limit procedure to the Einstein equations that involves an auxiliary gauge field with zero curvature.

In the second part of the course I discussed two special topics: (1) non-relativistic supersymmetry. Supersymmetry is a very special kind of symmetry. It is a spacetime symmetry in the sense that the action of two supersymmetries leads to a spacetime translation. Supersymmetry has been used as a possible symmetry of the Standard Model of particle physics. It also has generated new tools in many areas of physics and mathematics. A particularly interesting example of this is the supersymmetric localization technique that can be used to exactly compute partition functions of certain supersymmetric QFTs in curved backgrounds. These partition functions contain a wealth of information about the generic non-perturbative properties of the QFT. As of today, the supersymmetric localization technique has only been applied to relativistic models, since up to now no example of a non-relativistic supersymmetric QFT in a curved background has been constructed. (2) Non-relativistic matter. As it happens, the states that occur in the Fractional Quantum Hall Effect have a so-called Girvin-MacDonald-Platzman (GMP) gapped spin-2 mode that can be considered as a non-relativistic massive spin-2 particle whose dynamics is described by a spin-2 planar Schrödinger equation. In the last part of the course I showed how, at the linearized level, such a Schrödinger equation, can be obtained by applying a novel limit procedure to linearized massive gravity that only works in three spacetime dimensions. This limit leads to a fascinating connection between recent results obtained by the condensed matter and gravity communities.

Research

During my stay at the ESI I focussed on two research topics. First, I collaborated with Dr. J. Rosseel of Vienna University on the construction of a 3D non-relativistic Newton-Cartan supergravity that is sufficiently non-trivial to lead to the first example of a non-relativistic supersymmetric field theory in a curved background. The visit of Athanasios Chatzistavrakidis to the ESI in February 2018 was part of this collaboration. Based upon my positive experience with Johannes Lahnsteiner, a Master student at the University of Vienna who was also part of this collaboration, I offered him a PhD position at my own University. He accepted this offer and will start this position starting September 2018. As a second topic, I started to study, together with Dr. J. Rosseel and my PhD student Ceyda Şimşek, strings in a so-called string Newton-Cartan gravity background. String Newton-Cartan gravity has the distinguishing feature that the spacetime manifold has a so-called two-dimensional foliation allowing an absolute time and space direction. This work has evolved into a larger project, together with Prof. J. Gomis and Dr. Z. Yan of the Perimeter Institute (Waterloo, Canada).

Lecture Notes

I am in the process of writing lecture notes based upon my course, in collaboration with Dr. J. Hartong (University of Edinburgh), Dr. J. Rosseel (University of Vienna) and Prof. N. Obers (Niels Bohr Institute, Copenhagen). These lecture notes will be published in the series ESI Lectures in Mathematics and Physics.

Publications and preprints contributed

Eric Bergshoeff, Athanasios Chatzistavrakidis, Johannes Lahnsteiner, Luca Romano and Jan Rosseel, *Torsional supergravity for non-relativistic supersymmetry in curved backgrounds*, in preparation.

Eric Bergshoeff, Jaume Gomis, Jan Rosseel, Ceyda Şimşek and Ziqi Yan, *Newton-Cartan String Theory*, in preparation.

Francis Filbet: Introduction to Kinetic Theory: The Boltzmann Equation

Course

Then, some numerical approximation based on spectral methods has been presented and a rigorous convergence study has been performed. This presentation is based on several recent papers on the approximation of the Boltzmann equation in Kinetic Theory.

[1] Dimarco, G.; Pareschi, L. Numerical methods for kinetic equations. Acta Numer. 23 (2014), 369–520.

[2] Filbet, Francis; Pareschi, Lorenzo; Rey, Thomas On steady-state preserving spectral methods for homogeneous Boltzmann equations. C. R. Math. Acad. Sci. Paris 353 (2015), no. 4, 309–314.

[3] Gamba, Irene M.; Haack, Jeffrey R.; Hauck, Cory D.; Hu, Jingwei A fast spectral method for the Boltzmann collision operator with general collision kernels. SIAM J. Sci. Comput. 39 (2017), no. 4, B658–B674

[4] Dimarco, Giacomo; Loubère, Raphaël; Narski, Jacek; Rey, Thomas An efficient numerical method for solving the Boltzmann equation in multidimensions. J. Comput. Phys. 353 (2018), 46–81.

Research

Most of the research during the stay was conducted in collaboration with Ph.d. students and Post-doc from Vienna who attended my lectures. The research was closely connected to the lecture course as it focused on the approximation of the Boltzmann equation. It was a great opportunity for me to exchange with young people who develop different numerical techniques for the approximation of the Boltzmann equations.

Other people were more interested in modeling issues.

I also have interactions with J. Markus Melenk (TU Vienna), Ilaria Perugia (U Vienna), Christoph Schwab (ETH Zürich). These researchers work on numerical analysis and scientific computing in different topics elliptic problems, wave equations, etc. It was a fantastic opportunity to discuss about different numerical techniques which can be applied to kinetic theory.

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.

Lecture Notes

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

Erwin Schrödinger Lectures 2018

The Erwin Schrödinger Lectures are directed towards a general audience of mathematicians and physicists. In particular it is an intention of theses lectures to inform non-specialists and graduate students about recent developments and results in some area of mathematics or physics.

Ngô Bào Châu: Weierstrass preparation theorem and singularities in arc spaces

Speaker: Ngô Bào Châu (University of Chicago)

Ngô Bào Châu was born in Hanoi in 1972. He trained at École normale supérieure Paris and received his PhD at Orsay under the supervision of Gérard Laumon in 1997. In 2010, Professor Ngô was awarded a Fields Medal for "... his proof of the Fundamental Lemma in the theory of automorphic forms through the introduction of new algebro-geometric methods". He has been a professor at the University of Chicago since 2010.

Date: March 16, 2018

Abstract

Arc spaces have drawn considerable attention with the rise of the theory of motivic integration. In representation theory and harmonic analysis of/on groups defined over nonarchimedean local fields, arc spaces, and their singularities, also play a prominent role. The problem of understanding singularities of arc spaces becomes thus important both in motivic integration and geometric representation theory.

After earlier work of Grinberg and Kazhdan, Drinfeld gave a very convenient description of the formal completion of arc spaces with the help of a version of the Weierstrass preparation theorem with coefficients in Artin local rings. To go beyond the formal completion, we need a version of Weierstrass preparation theorem with arbitrary coefficients. I will describe the problems that arise in extending the Weiertrass preparation theorem to arbitrary coefficient rings and applications to understanding local structures of arc spaces.

Monika Henzinger: Dynamic Graph Algorithms: A Survey

Speaker: Monika Henzinger (University of Vienna)

Monika Henzinger is a professor of Computer Science at the University of Vienna and a former director of research at Google. She received a PhD from Princeton University in 1993 and subsequently held positions at Cornell University, Digital Equipment Corporation, the University of the Saarland and the École Polytechnique Fédérale in Lausanne. Monika Henzinger is the recipient of numerous grants and awards including an NSF Career Award, an honorary doctorate from the Technical University of Dortmund, as well as an ERC Advanced Grant. In her research, she focuses on combinatorial algorithms and data structure and their applications.

Date: December 6, 2018

Abstract

Real-world graphs are huge and many of them change dynamically. Thus to compute properties of these graphs we need dynamic graph algorithms that efficiently maintain properties of dynamically changing graphs. We present the state-of-the-art in dynamic graph algorithms, explaining some of the techniques that they use as well as recent progress in lower bounds.

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. On February 28, 2019 the Simons Junior Professorship of Nils Carqueville funded by the Simons Foundation terminated.

Teaching

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

Summer Term 2018:

Classical physics and symplectic geometry
Seminar, 2h, March 1 – June 30, 2018, Wednesday, 11:00–12:30

Dartstellungen algebraischer Strukturen
Lecture Course, 2h, March 1 – June 30, 2018, Tuesday, 16:45–18:15

Winter Term 2018/19:

Bachelorseminar
Seminar, 2h, October 1, 2018 – January 31, 2019, Friday 12:00–16:30

Introduction to category theory 1.5
Tutorial, 1h, October 1, 2018 – January 31, 2019, Friday 10:30–11:15

Introduction to category theory 1.5
Lecture Course, 3h, October 1, 2018 – January 31, 2019, Thursday 17:00–18:30, Friday 9:45–

10:30

At the "Young Researchers Integrability School and Workshop: A modern primer for 2D CFT") of the Erwin Schrödinger Institute he gave the following lecture course: *Algebraic and categorical structures in (T)QFT*

Research

In 2018 the research of Nils Carqueville focused on TQFTs on n-dimensional stratified bordisms as well as fully extended TQFTs in dimension 2. In particular, in a paper with I. Runkel and G. Schaumann he studied orbifolds of Reshetikhin-Turaev theory, and in a paper with Flavio Montiel Montoya he described Landau-Ginzburg models as fully extended TQFTs with values in a symmetric monoidal pivotal bicategory of non-semisimple character.

Further activities

In January 2019, Nils Carqueville co-organised a two-week workshop on quantum topology at ESI, together with Anton Mellit and Paul Wedrich. In 2018, Nils Carqueville applied for a Heisenberg Grant of the German Science Fund DFG to work on "Beyond semisimplicity in 3-dimensional TQFT"; the application was successful.

Visits from: Anna Beliakova (U Zurich), Domenico Fiorenza (La Sapienza Rome), Peter Guthmann (U Erlangen), Andras Juhasz (U Oxford), Calin Lazaroiu (U Pohang), Simona Paoli (U Leicester), Alexander Spies (U Erlangen), Lorant Szegedy (MPI Bonn), Alessando Valentino (U Zurich)

Visits to: U Edinburgh, U Erlangen, U Leicester, LMU Munich, U Paderborn, Ringberg Castle (talk at conference on "Geometry and Strings"), SISSA (lecture course "Higher structures in TQFT").

Prints and preprints contributed

N. Carqueville, I. Runkel, G. Schaumann, *Orbifolds of Reshetikhin-Turaev TQFTs*, [arXiv:1809.01483 [math.QA]]

N. Carqueville, F. Montiel Montoya, *Extending Landau-Ginzburg models to the point*, [arXiv:1809.10965 [math.QA]]

Junior Research Fellows Programme

The Junior Research Fellowship Programme supports external or local graduate students and recent postdocs (at most 5 years past receiving their PhD) to work on a project of their own in mathematics or physics that is either connected to a research direction carried out at the University of Vienna or to an ESI thematic programme. The ESI provides support for a Junior Research Fellow to work at the ESI for a time period between one and four months.

Vikas S. Krishnamurthy: New Frontiers in Applied Complex Analysis: Compressible Fluid Flows in multiply connected Domains

Vikas S. Krishnamurthy (Federal U of Pernambuco, Recife): April 1 – July 31, 2018:

Report

The theoretical study of vorticity and vortex dynamics is an important branch of fluid dynamics [1], and exact solutions to the PDEs governing the evolution of vorticity are rare and valuable. During my stay as a JRF at the ESI, I worked on four problems in vortex dynamics: (1) Stuart vortices on a rotating sphere, (2) The vorticity equation on the surface of a rotating sphere, (3) Finite time collapse of three point vortices in the plane, and (4) The compressible and steady motion of a hollow vortex pair.

Stuart vortices on the two-dimensional (2D) xy-plane are solutions of the vorticity equation $\nabla^2\psi = ae^{b\psi}$, which is a Liouville equation, where $\psi(x,y)$ is the streamfunction for the flow and a,b are constants [2]. For flows on the surface of a sphere parametrized by the spherical polar coordinates (θ,ϕ), the planar Laplacian ∇^2 is replaced by the Laplace-Beltrami operator ∇_Σ^2 and the resultant vorticity equation is $\nabla_\Sigma^2\psi = ae^{b\psi} + c$, where $\psi(\theta,\phi)$ is the streamfunction and a,b,c are constants [3]. Stuart vortices on a non-rotating sphere are solutions of this form of the vorticity equation and can be solved by transforming the vorticity equation into a Liouville equation using techniques from complex analysis such as stereographic projection [3]. In a joint project with my ESI host, Prof. A. Constantin, we have extended the Stuart vortex solutions to the case of sufficiently small regions on a rotating sphere. The vorticity equation on a rotating sphere takes the form $\nabla_\Sigma^2\psi = ae^{b\psi} + c + 2\omega\cos\theta$, where ω is a rotation parameter. The solution method combines the complex analysis techniques with elements of PDE theory to argue that solutions of the vorticity equation on a stationary sphere can be thought of as solutions on a rotating sphere, provided that we restrict our attention to sufficiently small regions, which are nevertheless large on an absolute scale [8].

The vorticity equation on the surface of a sphere differs from the planar vorticity equation in that the former is not exactly (mathematically) 2D, and requires approximations to ensure that it is 2D. Using only the shallow-water approximation, which means that we consider a thin layer of fluid on the surface of a sphere of large radius, the 2D vorticity equation can be derived from the governing Euler equation as shown in [4]. It is also possible to directly show that the three-dimensional vorticity equation reduces to the 2D vorticity equation on a sphere under the shallow-water approximation, this work has been submitted for publication as [9]. The research phase of this project (prior to the manuscript development stage) was carried out at ESI.

The motion of three point vortices in the unbounded plane is an integrable three-body problem [5]. A particular integrable motion of the three vortices that is of interest is one where they

converge into a single point in finite time. The point vortices form a Hamiltonian system with a time-conserved Hamiltonian. The finite time collapse of three point vortices preserves this Hamiltonian, as the singularity at finite time can be treated as a 'removable' singularity. Utilizing a recently developed geometric formulation of three vortex motion [6], explicit formulas relating the Hamiltonian energy and the collapse time, as well as new dynamical symmetries in the three-vortex problem have been worked out in [10]. The second half of this project, as well as the manuscript development, was carried out at ESI.

A point vortex is associated with a singular velocity field, which is unphysical. In recent years the *hollow vortex* model has gained increasing prominence. A hollow vortex is a finite area vortex in which the vorticity is concentrated entirely at the boundary, with stationary fluid within, and the velocity field is everywhere finite. Due to advances in the theory of analytic functions on multiply-connected domains, exact solutions for hollow vortex flows can be obtained using conformal mapping methods. The treatment of compressible vortex flows using complex analysis is a novel and new idea that is being developed at present, see for example [7]. At present, a configuration consisting of two steadily propagating hollow vortices of opposite signs in 2D is being considered, and the effect of compressibility is being investigated using perturbation methods. This is an ongoing project with partial results so far and a manuscript is still under preparation [11].

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Layne Frechette: Theory and Simulation of a Microscopic Model for Cation Exchange in Nanocrystals

Layne Frechette (UC, Berkeley): April 9 – May 11, 2018:

Report

My work during my 5 week stay at the ESI focused on nanocrystal phase transitions and dynamics.

Main Project: Cation Exchange

Cation exchange is a process in which the cations in a semiconductor nanocrystal are replaced by a different type of cation, while the anion sublattice remains intact [1]. This process has been exploited to synthesize nanocrystal heterostructures and metastable structures - useful in optical and electronic applications - that are inaccessible by conventional synthesis techniques [2]. However, the microscopic mechanisms by which cation exchange occurs remain unclear. Using molecular models developed to mimic heterogeneous solids, I have been studying the thermodynamics and kinetics of the cation exchange process.

In Vienna, I focused on the differences in phase separation behaviour between bulk and nanocrystal realizations of a model of heterogeneous solids. In this model, a solid is caricatured as a collection of atoms attached by central force springs in some lattice structure. In addition to their positions, there is also a "composition" or "spin" variable (type A or type B, spin up or spin down) associated with each atom. The natural bond length of the springs connecting adjacent atoms depends on the spin of those atoms. Explicitly, the Hamiltonian is:

$$H_{\text{elastic}} = \frac{K}{2} \sum_{\langle i,j \rangle} (r_{ij} - l_{ij})^2, \tag{1}$$

where the sum is over nearest-neighbour pairs, K is the spring constant, r_{ij} is the distance between atoms i and j, and l_{ij} is the natural bond length of the spring connecting i and j. This model is similar to some proposed in the literature in the context of phase separation in binary alloys [3] and spin-lattice coupling in spin-crossover compounds [4]. However, the equilibrium properties of such systems have not yet been thoroughly characterized, and models which use microscopically realistic dynamics have not yet been fully explored. Moreover, there is still much to explore in the context of nanocrystals, where one expects surface effects to become very important.

Monte Carlo simulations which I previously performed for a simple two-dimensional version of the model indicate that bulk and nanocrystal exhibit profoundly different behaviour: there is no phase separation in bulk, but there is in the nanocrystal. During my stay at the ESI I developed a theoretical understanding of this difference in behaviour. In bulk, phase separation incurs an extensive energetic penalty (one which grows linearly with system size) due to the constraints of periodic boundary conditions: it takes a macroscopic amount of energy to deform two domains of different preferred sizes to fit in the same simulation box. This is in contrast to the conventional Ising-like scenario, where the energy penalty for phase separation

is sub-extensive, depending only on the area of the interface separating the two domains. In the nanocrystal, on the other hand, free boundary conditions allow two domains of very different composition to coexist. This may help explain the observation that cation exchange reactions occur much more slowly in bulk than in nanocrystals [1].

In addition to my work on the thermodynamics of cation exchange, while at the ESI I developed a kinetic model for the cation exchange reaction, in collaboration with Christoph Dellago. In this model, the Hamiltonian is identical to that presented above, but the dynamics are specified by a set of possible moves with specified rate constants. The possible moves are: 1) Exchange move: the identity of an atom at the surface of the nanocrystal is changed. 2) Diffusion move: the identities of two adjacent atoms are swapped. 3) Bond move: bonds between adjacent atoms are made or broken. These moves must obey detailed balance, dictated by Boltzmann statistics and our model Hamiltonian. Professor Dellago and I will continue to collaborate on this work. We will perform computer simulations of the kinetic model, employing the methods of transition path sampling developed by Bolhuis, Chandler, Dellago, and Geissler, [5] to gain insight into the mechanism of cation exchange.

Other activities:

In addition to my main project, I worked an ongoing project of mine on the etching dynamics of gold nanocrystals [6]. Specifically, in this project I showed that the etchant concentration, which controls the driving force for the dissolution of nanocrystals, affects both the overall morphology and the microscopic roughness of the receding nanocrystal surfaces. While in Vienna I completed calculations and edited a manuscript for this project, in communication with my experimental collaborators at Berkeley. This work resulted in a recent publication [7].

I also initiated a collaboration with Andreas Singraber and Christoph Dellago on phase transitions in the material copper sulfide. Copper sulfide exhibits a so-called superionic phase transition from a low-temperature solid phase to a high-temperature phase in which the copper cation sublattice exhibits liquid-like properties while the anion sublattice remains solid-like [8]. A deeper understanding of this phase transition could assist efforts to employ copper sulfide as a solid electrolyte in batteries. While I was at the ESI, we began a project to simulate and analyze the dynamics of the transition using neural network potentials [9], [10].

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Bert Verbeke: A Unified Study of Geometrically and Topologically interesting Automorphisms of Lie Algebras

Bert Verbeke (KU Leuven): May 26 – July 1, 2018:

Report

An interesting question in spectral geometry posed by Hermann Weyl was whether or not isospectral manifolds are necessarily isometric. That this is not always the case, Milnor showed in 1964 by giving two isospectral but non-isometric flat tori in dimension 16 ([4]). In 1984, Gordon and Wilson were the first to construct continuous nilmanifolds which have the same spectrum but are not isometric ([2]). Recall that a nilmanifold is a quotient space $N\backslash G$, where N is a uniform lattice and G is a connected and simply connected nilpotent Lie group G.

To obtain their result, Gordon and Wilson used the notion of almost inner automorphisms of nilpotent Lie groups. An automorphism of a group is said to be almost inner if and only if it is an automorphism where each group element is conjugate to its image. So, this condition is related to, but less strict than the one for an inner automorphism. A nilpotent Lie group which

admits a lattice and an almost inner automorphism which is not inner can be used to obtain a family of continuous isospectral and non-isometric nilmanifolds. Hence, the existence problem of this kind of automorphisms on a given (virtually) nilpotent group is very interesting. However, up till now, these almost inner automorphisms have only been considered from a geometric point of view ([2, 3, 5]).

Another notion is that of an almost inner derivation of a Lie algebra, the corresponding concept on the Lie algebra level. A derivation D of a Lie algebra $\mathfrak{g}$ is called almost inner if and only if it is a derivation where every element is adjoint to its image. This means that for every $x \in \mathfrak{g}$, there exists $y \in \mathfrak{g}$ such that $D(x) = [x, y]$. Hence, this condition is less strict than the one for an inner derivation, where every element is mapped to the Lie bracket of itself with some fixed element. The notion of an almost inner derivation has almost only been considered for some 2-step nilpotent Lie algebras and only for the fields $\mathbb{R}$ and $\mathbb{C}$.

Together with prof. Karel Dekimpe and prof. Dietrich Burde, I am working on an algebraic approach to study these almost inner derivations. The geometric motivation only makes sense for nilpotent Lie algebras over the real and complex field. However, from an algebraic point of view, there is no reason to restrict to these Lie algebras and these fields, so we consider Lie algebras in big generality. In [1], we obtained the first algebraic results concerning this topic. For instance, we computed all almost inner derivations for low-dimensional complex Lie algebras and showed that all almost inner derivations are inner for different classes of complex Lie algebras, such as 2-step nilpotent Lie algebras determined by graphs, free 2-step and 3-step nilpotent Lie algebras, free metabelian nilpotent Lie algebras on two generators, almost abelian Lie algebras and triangular Lie algebras. Further, we also constructed families of Lie algebras with non-trivial almost inner derivations. The space of non-inner almost inner derivations can even be arbitrarily large.

Now, the three of us are working on a second paper concerning this notion. During my stay at the Erwin Schrödinger Institute from May 26 to July 1, I worked in close collaboration with prof. Dietrich Burde from the University of Vienna. We focused on two specific topics. First, we finished the construction of a class of Lie algebras for which holds that every derivation is almost inner. More concretely, for each $n \geq 13$ and for a field K of characteristic zero, we found a characteristically nilpotent and filiform Lie algebra $\mathfrak{g}$ over K of dimension n with $\mathrm{Inn}(\mathfrak{g}) \neq \mathrm{AID}(\mathfrak{g}) = \mathrm{Der}(\mathfrak{g})$. These are the first known examples having this property.

For the second topic, we consider a finite field extension K of k, where k has characteristic zero. Let $\mathfrak{g}_k$ be a Lie algebra over k and let $\mathfrak{g}_K := \mathfrak{g} \otimes_k K$ be the corresponding Lie algebra over K. We are interested in the almost inner derivations of $\mathfrak{g}_k$ respectively $\mathfrak{g}_K$ and the relations between them. We showed that if a $\mathfrak{g}_K$ admits a non-trivial almost inner derivation, then also $\mathfrak{g}_k$. However, the converse does not hold in general. This shows that the algebraic structure of $\mathrm{Der}(\mathfrak{g})$, which is closely related to the structure of $\mathrm{Der}(\mathfrak{g} \otimes_k K)$, does not give all the information about the existence problem.

We can also consider $\mathfrak{g}_K$ as a Lie algebra over k and denote this so-called underlying Lie algebra by $\mathfrak{g}_k'$. Note that $\mathfrak{g}_k' = \mathfrak{g}_K$ holds as vector spaces. For these Lie algebras, we found a method to construct new almost inner derivations of $\mathfrak{g}_k'$ based on the almost inner derivations of $\mathfrak{g}_K$.

The second paper concerning almost inner derivations, which will also contain other topics than the two above, is still in preparation.

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Publications and preprints contributed

Burde D., Dekimpe K. and Verbeke B., *Almost inner derivations of Lie algebras II*, in preparation.

Zahra Mirzaiyan: Soft Hair on Black Holes in Four Dimensional Space-Times

Zahra Mirzaiyan (Isfahan U of Technology): July 1 – October 31, 2018:

Report

The notion of "soft hair" — introduced by Hawking, Perry and Strominger — refers to zero energy excitations of black holes [1]. Recently a concrete implementation of the "soft hair" idea in three spacetime dimensions [2] was provided, which differs in small but significant aspects from earlier proposals [3] [4]. They found new boundary conditions that lead to infinite copies of the Heisenberg algebra (rather than BMS) as asymptotic symmetries; equivalently, the asymptotic symmetries are generated by two $\mathfrak{u}(1)$ current algebras. The same set of asymptotic symmetries was found for BTZ black holes in Einstein gravity with negative cosmological constant [2] and flat space cosmologies [5]. One of the main outcomes for black hole physics so far is the discovery of a new and apparently fairly universal entropy formula in three dimensions

$$S = 2\pi \left(J_0^+ + J_0^- \right) \tag{1}$$

where $J_0^\pm$ are zero modes of the two $\mathfrak{u}(1)$ current algebras. This new entropy formula together with further algebraic considerations has led to an explicit proposal for BTZ black hole microstates [7, 8] which correctly reproduces the formula (1) as well as its semi-classical log corrections calculated in [9].

The main goal of my research project was to generalize these results to the phenomenologically interesting case of four spacetime dimensions. In the initial phase of my research stay in Vienna, we focused on four- and higher-dimensional versions of the new entropy formula (1). In particular, we attempted to check its universality by considering in four dimensions black holes with a cosmological constant with toroidal horizon topology (in anti-de Sitter) namely toroidal Kerr-AdS black holes. In five dimensions we were interested in studying Myers–Perry

black holes and possible generalizations thereof so see how the entropy formula changes as the dimension is increased.

We also attempted to generalize the microstate proposal of [7, 8] to four dimensions. For concreteness, we focused on Kerr-anti-de Sitter black holes in four spacetime dimensions with toroidal horizon topology $(S^1 \times S^1)$ or (T^2). This particular topology may help to avoid delicate issues with singularities of "superrotation"-generators on the 2-sphere. Based on the recent proposal results [10], we found the near horizon conserved charges and showed that the near horizon symmetries can be represented by Heisenberg algebras. For each circle we can write the near horizon algebra as

$$\{\mathcal{P}_{Xn}, \mathcal{J}_{Xm}\} = \frac{n}{8\pi G}\delta_{n+m,0}, \tag{2}$$

$$\{\mathcal{P}_{Xn}, \mathcal{J}_{Xm}\} = \frac{n}{8\pi G}\delta_{n+m,0}. \tag{3}$$

where, the generators $\mathcal{P}$ and $\mathcal{J}$ are called "supertranslations" and "superrotations" and $X(Y)$ is related to the $X(Y)$-circle. We wish to continue this research and have an explicit construction for a complete set of microstates of a non-extremal black hole in four spacetime dimensions and recover Bekestein-Hawking entropy for toroidal Kerr-AdS black holes.

We also tried to continue the upcoming proposal [10] by working through some more set of examples in higher dimensions than four, like five dimensional Myers-Perry by finding the near horizon conserved charges.

Results

During my stay at ESI, I had the chance to collaborate with my host, Daniel Grumiller. We showed that for toroidal Kerr-AdS black holes in four spacetime dimensions the near horizon symmetries can be represented as Heisenberge algebras as an example of black holes with flat horizon. We wish to generalize the microstate proposal to four dimensions [7] to recover the Bekestein-Hawking entropy for these black holes which is an ongoing research [*1]. We also found the near horizon conserved charges for five dimensional Myers-Perry black holes in order to explicitly have an example of Heisenberge algebra as the near horizon symmetries in higher dimensions which is a project that I wish to continue with Daniel Grumiller (my host at TU Wien) and some collaborators in Iran.

Moreover, I had the chance to finish two projects [*2] and [*3] with some colleagues at Harvard University, USA and Scuola Internazionale Superiore di Studi Avanzati (SISSA), Italy and contribute in a project [*4] collaborating with my PhD supervisor at my home university, Isfahan University of Technology (IUT), Iran.

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Publications and preprints contributed

*1. Daniel Grumiller, Zahra Mirzaiyan and M.M Sheikh-Jabbari, *Horizon fluff proposal for toroidal-Kerr-AdS black holes*, Ongoing project.

*2. Elizabeth Himwich, Zahra Mirzaiyan and Sabrina Pasterski, *A note on the subleading soft graviton*, to appear.

*3. Ramit Dey, Stefano Liberati, Zahra Mirzaiyan and Daniele paranzetti, *Origin of Hawking quanta from the renormalized stress energy tensor vs. effective temperature*, to appear.

*4. Hamideh Nadi, Behrouz Mirza and Zahra Mirzaiyan, *Electromagnetic self-force in the five dimensional Myers-Perry space time*, To be submitted.

Matteo Cavaleri: Approximations and computations in infinite groups

Matteo Cavaleri (Unicusano U, Rome): July 15 – September 15, 2018:

Report

In Geometric Group Theory, several properties of finitely generated groups, such as soficity, amenability, and quasi-isometries, are related with certain approximation problems. Moreover, in the last decades, approximation played an important role also in Group Computability, for example, in relation with generic and coarse algorithmic decision problems [5]. My research constitutes the first attempt, in the specific framework of Group Theory, to find a common treatment of these two directions. As an example, I introduced and studied several definitions of *effective amenability*, for instance, computability of Følner sets and of Reiter functions [2]. As a byproduct, I answered open questions of Vershik [7] and Gromov [4] about the shape of Følner sets and the computability of Følner functions.

A fruitful approach to several open problems related to metric approximation of groups, is to investigate *stability*. A "system" is called stable if, in a specific sense, an *almost* solution is always *close* to an *exact* solution. As an example, *stability in permutations* with respect to the Hamming length (see [1],[3]) plays a crucial role in the study of soficity. In fact, stability of the system of defining relations in the presentation of a sofic group, ensures residual finiteness: this provides a possible strategy for constructing non-sofic groups.

I adopted this approach also in Computability Theory: under certain hypotheses, existence of a *partial* algorithm (solving a problem on a *proper* subset of inputs), implies existence of a *total* algorithm (solving the problem on *all* inputs). In this direction, I proved [2] that if a computably presented (finitely generated) amenable group has *solvable generic* Equality Problem, then it has *solvable* Equality Problem (on the whole group) and therefore solvable Word Problem. This way, I provided the first examples of finitely presented groups with unsolvable generic Equality Problem.

During these two months at the ESI, my work was also joint with Angela Carnevale (also a JRF at the ESI): we combined the previous approach with new notions of genericity. Banach densities are well known and studied for abelian and amenable groups; we introduced *upper Banach genericity* (shortly, UB-genericity) for subsets of the free group $\mathbb{F}_d$. The first main application is the following.

Theorem A *If a finitely generated group Γ has solvable Equality Problem on a subset $S \times S \subset \mathbb{F}_d \times \mathbb{F}_d$, where S is UB-generic, then Γ has solvable Word Problem.*

Since UB-genericity is a weaker notion than classic genericity, as a byproduct, we answered an open question from [6], generalizing one of the main results from [2]:

Corollary A *For finitely generated groups, the generic Equality Problem (in the sense of [6]) is equivalent to the Word Problem.*

Moreover, we propose a variant of genericity for the Equality Problem, closer to the original definition of genericity given in [5], namely by measuring subsets directly within $\mathbb{F}_d \times \mathbb{F}_d$. We then prove equivalence between this new generic Equality Problem and the generic Word Problem.

In order to investigate generic unsolvability phenomena, in [6] the authors introduced the new class of *algorithmically finite* groups, consisting of those groups that admit no computably enumerable infinite sequence of pairwise distinct group elements. The main result of [6] is the existence of computably presented infinite groups that are algorithmically finite. It is a very interesting and challenging problem whether or not finitely presented examples exist. Algorithmically finite groups are characterized in terms of the Equality Problem: they are those groups Γ such that if the Equality Problem is solvable on $S \times S$, then the words in S represent a finite number of distinct elements in Γ. Analogously, we consider the class of groups with unsolvable UB-generic Word Problem and we show that it contains all algorithmically finite groups.

Theorem B *A finitely generated group Γ has solvable UB-generic Word Problem if and only if there exist a computably enumerable infinite sequence of words with strictly increasing length in Γ.*

Corollary B *Algorithmically finite groups have unsolvable UB-generic Word Problem.*

Since UB-genericity is a weaker notion than classic genericity, algorithmically finite groups have also unsolvable generic Word Problem. We believe that under suitable hypotheses of approximability (amenability, residual finiteness, soficity, etc.) or, at least, of computable approximations (Følner sets, sofic dimension, etc.), we can further investigate the Word Problem for

algorithmically finite groups with our new densities.

The mathematical discussions during these months with Prof. Goulnara Arzhantseva and Dr. Christopher Cashen (both from the University of Vienna) have been essential for my work. In fact, other directions of my research include the investigation of the Word Problem for groups of intermediate growth and the study of the quasi-isometric invariance of the Word Problem for computably presented groups. In this direction, I obtained some partial results, and my work is still in progress. Finally, I started a collaboration with Arzhantseva in order to find new kinds of approximations for computability, that may be used as a new tool for the investigation of soficity.

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A. Carnevale, M. Cavaleri, *Partial Word and Equality problems and Banach densities*, arXiv:1811.11134.

Angela Carnevale: Enumeration of Matrices, Hyperoctahedral Groups, and Generating Functions

Angela Carnevale (U Bielefeld): July 30 – November 30, 2018:

Report

Combinatorics often offers invaluable tools in the search for solutions to problems of an algebraic and geometric nature. My research is often motivated by the search for combinatorial objects and techniques that can be used to this aim: statistics on permutations, words and Coxeter groups, generating functions, ordered structures, to mention a few. In recent years, I focused in particular on combinatorial solutions to problems in asymptotic group theory. During my stay at ESI, I had the opportunity to carry out research projects of various flavours, involving purely

combinatorial topics, as well as in combinatorial and asymptotic group theory.

During the first six weeks of my stay, I focused on a joint project with Matteo Cavaleri (also JRF at ESI) regarding partial Word and Equality problems for finitely generated groups. We proved both *solvability* and *unsolvability* statements. Results of the former type include solvability of the Word Problem under the hypothesis of solvability of the generic—in a specific sense— Equality Problem. Results of the latter type include unsolvability of the generic (even more, Upper Banach generic) Word Problem for algorithmically finite groups (cf. [3]). This joint work resulted in the preprint [P2].

In a joint work with Michael M. Schein (Bar-Ilan) and C. Voll (Bielefeld) my efforts were devoted to introducing a new class of combinatorially defined rational functions. They arise as a technical tool to deduce explicit formulae for local ideal zeta functions associated to a large class of nilpotent Lie rings. Specifically, functions in this new class, *generalized Igusa functions*, are rational functions associated to integer compositions. They generalize the weak order zeta functions defined in [4] and, as predicted by deep results (see [6]), satisfy properties of combinatorial reciprocity. These are proved in a purely combinatorial way by means of Möbius-like functions in [P3].

Finally, I explored various directions of research in the context of enumerative problems related to rank varieties of matrices. More precisely, my interest is in understanding some remarkable enumerative properties shared by rank varieties of matrices satisfying certain linear constraints on their entries, on one hand, and distributions of statistics on permutation groups, on the other. A well-known formula for the distribution of the number of inversions on certain quotients of the symmetric groups can be geometrically interpreted: Schubert varieties are the key to this geometric interpretation. Sign-twisted formulae of a similar flavour give both the distribution of the Coxeter length on certain quotients of the groups of signed permutations and the number of generic matrices over a finite field $\mathbb{F}_q$ and given rank. As conjectured in [5] and proved in [1], choosing a different sign-twist and another length-like statistic, known as *odd length* yields the number of *symmetric* matrices over $\mathbb{F}_q$ of given rank. As a first step towards understanding the geometry behind this intriguing identity, in a joint project with F. Brenti (Rome), we defined the odd analogue of the diagram of a permutation and, by means of this combinatorial object, we defined odd analogues of the classical Schubert varieties. One of main results states that the *odd Schubert variety* associated with a permutation is a complex projective variety and its dimension is the odd length of the permutation. The definition of odd diagrams led to a number of interesting combinatorial results and conjectures. Unlike the classical permutation diagrams, odd diagrams are not in bijection with permutations. This motivated us to look for classes of permutations for which the odd diagram faithfully encodes the elements of the class. We conjecture that the function associating a permutation with its odd diagram is injective on the class of 213- and of 312-avoiding permutations. These and other results and conjectures will be included in a forthcoming version of [P1].

Another direction of research that I pursued within this project is that of looking for classes of matrices for which the enumeration according to rank can be interpreted in terms of sign-twisted distribution of statistics on quotients of the groups of signed permutations. Previous results show that adding one linear constraint (from generic matrices to traceless matrices) preserves this feature and is only reflected in a slight modification of the statistic; cf. [2]. Experimental evidence suggests, however, that adding more constraints breaks this connection. In particular, intersecting the variety of traceless matrices with a hyperplane defines rank varieties

which no longer share enumerative properties with the hyperoctahedral groups. The varieties obtained by adding more linear constraints on their entries exhibit other remarkable enumerative and geometric properties, which became the main object of study in a new joint research project with T. Rossmann (Galway).

During my stay at ESI, I had the great opportunity to interact with two very active research groups in Vienna: the research group of G. Arzhantseva and the combinatorics group of C. Krattenthaler. Among other activities, I gave a talk in the Geometry and Analysis on groups research seminar at the University of Vienna and participated in the meetings of the Arbeitsgemeinschaft Diskrete Mathematik at TU Wien.

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[P1.] F. Brenti, A. Carnevale, *Signed generating functions for odd inversions on descent classes*, new version in preparation.

[P2.] A. Carnevale, M. Cavaleri, *Partial Word and Equality Problems and Banach densities*, arXiv:1811.11134[math.GR].

[P3.] A. Carnevale, M.M. Schein, C. Voll, *Generalized Igusa functions and ideal growth in nilpotent Lie rings*, in preparation.

Andreas Zöttl: Coarse-grained hydrodynamic simulations of driven colloids in macromolecular polymer solutions

Andreas Zöttl (ESPCI Paris): September 1 – December 31, 2018:

Report

During my stay at the ESI I performed and analyzed hydrodynamic simulations of driven nano- and microparticles suspended in explicitly modelled polymeric fluids. By carrying out this work I used a computer program which I previously developed during my stay at the University of Oxford where I was working in the group of Prof. Julia Yeomans. So far little experimental,

numerical and theoretical work has been performed regarding the motion of driven spherical and elongated particles in complex fluids, despite the relevance for biological and technological applications, such as the transport of drugs or food particles through biological fluids in the human body which typically contain high-molecular weight polymeric material.

I started by defining the shape of the driven particles as axially symmetric superellipsoids, which can be used to model spherical, ellipsoidal, and rodlike particles by using the same shape function but different shape parameters. Then I constructed suspensions of flexible and semi-flexible polymers at different densities which consist of spherical beads connected by quasi-rigid springs. Both the superellipsoidal particle and the polymers where then suspended in a Newtonian background fluid consisting of pointlike effective fluid particles modeled by multiparticle collision dynamics (MPCD). These particles perform alternating streaming and collision steps in order to solve the Navier Stokes equations on a coarse-grained level. The solid particle, which is driven by applying a constant force along its major axis, and the polymers interact with the fluid particles both in the streaming an collision step. This algorithm creates the correct flucuating hydrodynamic flow fields around the particle, and simulates the stochastic dynamics of the particle in the presence of polymers.

We first determined the velocities of the particles depending on the density of the polymers, and for different driving forces. We observed that the particles move faster than expected from a simple Stokes-Einstein relation between the viscosity of the fluid and the mobility of the particles. We found that this is due to the occurence of polymer depletion layers around the particles, which locally create viscosity gradients on length scales comparable to the depletion layer thickness. This is also reflected by the flow fields around the particles which decay faster close to particles. This can indeed be explained by using a simple two-fluid model which approximates the viscosity gradients due to polymer depletion around the particle by a step function, where in the inner layer the fluid has approximately the viscosity of water, and outside the bulk viscosity of the polymeric fluid [1,2]. We also investigated the effects of increasing the driving force. First, we observed that for sufficiently strong driving forces the distribution of polymers around the particles become nonhomogeneous. When the particle is too fast, pushed-away polymers are too slow to immediatly fill the polymer-poor area behind the particle. In addition we found that polymers get stretched for relatively strong driving forces, in particular, they tend to orient parallel to the particle at the back, and perpendicular to the particle at the front, hinting to some sort of elastic behavior.

All in all, the results obtained during my stay at the ESI helps to better understand the motion of nano-and microparticles moving through polymeric fluids.

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Seminars and colloquia outside main programmes and workshops

477 seminar and colloquia talks have taken place at the ESI in 2018 including the following individual talks.

2018 03 16 , N. Châu: "Weierstrass preparation theorem and singularities in arc spaces"
2018 04 16 , R. Moessner: "Thermodynamics and order beyond equilibrium - from eigenstate thermalisation to time crystals"
2018 04 23 , G. Mussardo: "The Generalised Riemann Hypothesis"
2018 12 06 , M. Henzinger: "Erwin Schrödinger Lecture: Dynamic Graph Algorithms: A Survey"

ESI Research Documentation

ESI research in 2018: publications and arXiv preprints

The following codes indicate the association of publications and preprints with specific ESI activities:

AHM = Mathematical Aspects of Physical Oceanography
BTZ = Geometric Correspondences of Gauge Theories
CGP = Mathematical Challenges of Structured Function Systems
CMF = Advances in Chemical Reaction Network Theory
CSR = Bivariant K-theory in geometry and physics
DFS = New Trends in the Variational Modeling of Failure Phenomena
GNB = Rigidity and Flexibility of Geometric Structures
JRF = Junior Research Fellow
GLO = Analysis and CR Geometry
MSC = Quantum Paths
OST = Matrix Models for Noncommutative Geometry and String Theory
PSH = Numerical Analysis of Complex PDE Models in the Sciences
RIT = Research in Teams
SRF = Senior Research Fellows
Symposium = Symposium on: Probability in the Sciences Symposium
WTW = Moonshine

THEMATIC PROGRAMMES

Mathematical Aspects of Physical Oceanography (AHM)

P. Miron, F. J. Beron-Vera, M. J. Olascoaga and P. Koltai, *Markov-chain-inspired search for MH370*, AIP Chaos: An Interdisciplinary Journal of Nonlinear Science, https://aip.scitation.org/journal/cha, DOI: https://doi.org/10.1063/1.5092132.

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N. Paldor, *Recent advances in linear wave theory on the spherical earth*, Elsevier, Deep-Sea Research Part II: Topical Studies in Oceanography 160 (2019), Pages 63-67.

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Quantum Paths (MSC)

V. Alba, B. Bertini, M. Fagotti, *Entanglement evolution and generalised hydrodynamics: interacting integrable systems*, arXiv:1903.00467 [cond-mat.stat-mech].

V. Alba, S.N. Santalla, P. Ruggiero, J. Rodriguez-Laguna, P. Calabrese, G. Sierra, *Unusual area-law violation in random inhomogeneous systems*, arXiv:1807.04179 [cond-mat.stat-el].

A. Bastianello, P. Calabrese, *Entanglement evolution and generalised hydrodynamics: noninteracting systems*, arXiv:1807.10176 [cond-mat.stat-mech].

B. Bertini, M. Fagotti, L. Piroli, P. Calabrese, *Entanglement evolution and generalised hydrodynamics: noninteracting systems*, arXiv:1805.01884 [cond-mat.stat-mech].

B. Bertini, P. Kos, T. Prosen, *Entanglement spreading in a minimal model of maximal many-body quantum chaos*, arXiv:1812.05090 [cond-mat.stat-mech].

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S. Czischek, M. Gärttner, M. Oberthaler, M. Kastner, T. Gasenzer, *Quenches near criticality of the quantum Ising chain—power and limitations of the discrete truncated Wigner approximation*, arXiv:1805.05221 [quant-ph].

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Numerical Analysis of Complex PDE Models in the Sciences (PSH)

F. Bonizzoni, F. Nobile, I. Perugia, D. Pradovera, *Fast Least-Squares Padé approximation of problems with normal operators and meromorphic structure*, arXiv:1808.03112 [math.NA].

M. Feischl, D. Peterseim, *Sparse Compression of Expected Solution Operators*, arXiv:1807.01741 [math.NA].

P. Kürschner, S. Dolgov, K. D. Harris, P. Benner, *Greedy low-rank algorithm for spatial connectome regression*, arXiv:1808.05510 [math.NA].

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Bivariant K-theory in geometry and physics (CSR)

S. Hayashi, *Toeplitz operators on concave corners and topologically protected corner states*, arXiv:1902.01533 [math-ph].

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K. van den Dungen, *The Kasparov product on submersions of open manifolds*, arXiv:1811.07824 [math. KT].

WORKSHOPS

Mathematical Challenges of Structured Function Systems (CGP)

K.-M. Perfekt, *The transmission problem on a three-dimensional wedge*, arXiv:1805.12544 [math.AP].

Matrix Models for Noncommutative Geometry and String Theory (OST)

A. Stern, C. Xu, *Signature change in matrix model solutions*, arXiv:1808.07963 [hep-th].

New Trends in the Variational Modeling of Failure Phenomena (DFS)

M. Bonacini, E. Davoli, M. Morandotti, *Analysis of a perturbed Cahn-Hilliard model for Langmuir-Blodgett films*, arXiv:1809.07566 [math.AP].

I. Lucardesi, M. Morandotti, R. Scala, D. Zucco, *Upscaling of screw dislocations with increasing tangential strain*, arXiv:1808.08898 [math.AP].

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E. Davoli, I. Fonseca, P. Liu, *Adaptive image processing: first order PDE constraint regularizers and a bilevel training scheme*, arXiv:1902.01122 [math.AP].

E. Davoli, M. Friedrich, *Two-well rigidity and multidimensional sharp-interface limits for solid-solid phase transitions*, Submitted, 2018 (Preprint available on http://cvgmt.sns.it/paper/4071/).

Geometric Correspondences of Gauge Theories (BTZ)

J. Stoppa, *A note on BPS structures and Gopakumar-Vafa invariants*, arXiv:1812.07454 [math. AG].

Moonshine (WTW)

V. M. Aricheta, *Supersingular elliptic curves and moonshine*, arXiv:1809.0742 [math.NT].

A. Chattopadhyaya and J. R. David, *Properties of dyons in $\mathcal{N} = 4$ theories at small charges*, arXiv:1810.12060 [hep-th].

A. Banlaki, A. Chowdhury, A. Kidambi and M. Schimpf, *On Mathieu moonshine and Gromov-Witten invariants*, arXiv:1811.11619 [hep-th].

Rigidity and Flexibility of Geometric Structure (GNB)

V.M. Aricheta, *Supersingular Elliptic Curves and Moonshine*, arXiv:1809.07421 [math.NT].

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Advances in Chemical Reaction Network Theory (CMF)

B. Boros, J. Hofbauer, S. Müller, G. Regensburger, *Planar S-systems: Global stability and the center problem*, Discrete and Continuous Dynamical Systems – Series A, 39(2): 707–727, 2019, https://doi.org/10.3934/dcds.2019029.

Yongjun Li, Valery Romanovski, *Hopf Bifurcations in a Predator-Prey Model with an Omnivore*, Submitted, 2018.

Analysis and CR Geometry (GLO)

F. Forstneric, *H-principle for complex contact structures on Stein manifolds*, arxiv.org/abs/1810.12943, [math.CV].

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L. D. Edholm, J. D. McNea *Sobolev mapping of some holomorphic projections*, arXiv:1904.04383, [math.CV].

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I. Cheltsov, J. Park, C. Shramov, *Delta invariants of singular del Pezzo surfaces*, arXiv:1809.09221 [math.AG].

I. Cheltsov, J. Park, C. Shramov, H. Ahmadinezhad, *On geometry of Fano 3-fold hypersurfaces*, in preparation.

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A. Gasull, A. Geyer, V. Mañosa, *Periodic traveling waves for perturbed partial differential equations.* In preparation.

A. Gasull, A. Geyer, F. Mañosas, *Chebyshev Criteria for Abelian integrals with applications to perturbations of periodic non-autonomous ODEs.* In preparation.

A. Gasull, V. Mañosa, *Periodic orbits of discrete and continuous dynamical systems via Poincaré-Miranda theorem*, arXiv:1809.06208 [math.DS].

SENIOR RESEARCH FELLOWS PROGRAMME (SRF)

E. Bergshoeff, A. Chatzistavrakidis, J. Lahnsteiner, L. Romano, J. Rosseel, *Torsional supergravity for non-relativistic supersymmetry in curved backgrounds*, in preparation.

E. Bergshoeff, J. Gomis, J. Rosseel, C. Şimşek, Z. Yan, *Newton-Cartan String Theory*, in preparation.

SIMONS JUNIOR PROFESSOR NILS CARQUEVILLE

N. Carqueville, I. Runkel, G. Schaumann, *Orbifolds of Reshetikhin-Turaev TQFTs*, arXiv:1809.01483 [math.QA].

N. Carqueville, F. Montiel Montoya, *Extending Landau-Ginzburg models to the point*, arXiv:1809.10965 [math.QA].

JUNIOR RESEARCH FELLOWS PROGRAMME (JRF)

A. Carnevale, M. Cavaleri, *Partial Word and Equality problems and Banach densities*, arXiv:1811.11134 [math.GR].

F. Brenti, A. Carnevale, *Signed generating functions for odd inversions on descent classes*, new version in preparation.

A. Carnevale, M.M. Schein, C. Voll, *Generalized Igusa functions and ideal growth in nilpotent Lie rings*, in preparation.

M.R. Hauwiller, L.B. Frechette, M.R. Jones, J.C. Ondry, G.M. Rotskoff, P. Geissler, A.P. Alivisatos, *Unraveling Kinetically-Driven Mechanisms of Gold Nanocrystal Shape Transformations Using Graphene Liquid Cell Electron Microscopy*, Nano Letters (2018), DOI: https://doi.org/10.1021/acs.nanolett.8b02337.

L.B. Frechette, C. Dellago, P.L. Geissler, *Superlattice phases in cation exchange nanocrystals*, in preparation.

A. Constantin, V. S. Krishnamurthy, *Stuart-type vortices on a rotating sphere*, J. Fluid Mech., under review.

V. S. Krishnamurthy, *The vorticity equation on a rotating sphere and the shallow-fluid approximation*, Disc. Cont. Dyn. Sys. A, under review.

V. S. Krishnamurthy, M. A. Stremler, *Finite-time collapse of three point vortices in the plane*, Reg. Chaotic Dyn, **23**(5) (2018), 530–550. Manuscript under preparation.

D. Grumiller, Z. Mirzaiyan, M.M. Sheikh-Jabbari, *Horizon fluff proposal for toroidal-Kerr-AdS black holes*, ongoing project.

E. Himwich, Z. Mirzaiyan, S. Pasterski, *A note on the subleading soft graviton*, to appear.

R. Dey, S. Liberati, Z. Mirzaiyan, D. Paranzetti, *Origin of Hawking quanta from the renormalized stress energy tensor vs. effective temperature*, to appear.

H. Nadi, B. Mirza, Z. Mirzaiyan, *Electromagnetic self-force in the five dimensional Myers-Perry space time*, To be submitted.

D. Burde, K. Dekimpe, B. Verbeke, *Almost inner derivations of Lie algebras II*, in preparation.

P. Wirnsberger, C. Dellago, D. Frenkel, A. Reinhardt, *Theoretical prediction of thermal polarisation*, arXiv:1804.03624 [cond-mat.stat-mech]. Phys. Rev. Lett. **120**, 226001, 2018, see also https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.120.226001.

A. Zöttl, J. M. Yeomans, *Driven spheres, ellipsoids and rods in explicitly modeled polymer solutions*, arXiv:1901.06243 [cond-mat.soft].

ESI research in previous years: additional publications and arXiv preprints

The following papers and publications complement the ESI preprints already taken into account in the previous years.

AGS = Measured Group Theory, 2016
CBS = Geometry and Relativity, 2017
JRF = Junior Research Fellow, 2017
PDG = Tractability of High Dimensional Problems and Discrepancy, 2017
RIT = Research in Team SJ = ESI-CECAM Workshop: Physics and Chemistry at Fluid/Fluid

Interfaces, 2017

A. Carderi, D. Gaboriau, M. de la Salle, *Non-standard limits of graphs and some orbit equivalence invariants*, arXiv:1812.00704 [math.GR], AGS.

A. Compelli, *Solitary wave solution of Flat Surface Internal Geophysical Waves with Vorticity*, now published: AIP Conference Proceedings **1895**, 040002 (2017), DOI: https://doi.org/10.1063/1.5007369, arXiv:1708.06653 [physics.u-dyn], RIT 2017.

A. C. Compelli, R. I. Ivanov, C. I. Martin, M. D. Todorov, *Surface waves over currents and uneven bottom*, Elsevier, Deep-Sea Research Part II 160 (2019) 25-31, DOI: https://doi.org/10.1016/j.dsr2.2018.11.004, RIT 2017.

G. Racher, *Square-integrable representations and multipliers*, paper, AGS.

M. Gnewuch, M. Hefter, A. Hinrichs, K. Ritter, G. W. Wasilkowski, *Embeddings for Infinite-Dimensional Integration and L2-Approximation with Increasing Smoothness*, arXiv:1809.07103 [math.NA], PDG.

R.J. Kunsch, E. Novak, D. Rudolf, *Solvable integration problems and optimal sample size selection*, arXiv:1805.08637 [math.NA], PDG.

S. V. Lishchuk, J. Fischer, *Long range corrections in liquid-vapor interface simulations*, The Journal of Chemical Physics 149, 091102 (2018), DOI: https://doi.org/10.1063/1.5048925, SJ.

X. Rong, R. Ettelaie, S.V. Lishchuk, H. Cheng, N. Zhao, F. Xiao, F. Cheng, H. Yang, *Liquid marble-derived solid-liquid hybrid superparticles for CO2 capture*, Citation: Nature Communications, volume 10, Article number: 1854 (2019) DOI: https://doi.org/10.1038/s41467-019-09805-7, SJ.

O. O. Fatoba, R. Leiva-Garcia, S. V. Lishchuk, N. O. Larrosa, R. Akid, *Simulation of stress-assisted localised corrosion using a cellular automaton finite element approach*, Corrosion Science, Volume 137, June 2018, Pages 83-97, SJ.

J.D.E. Grant, M. Kunzinger, C. Sämann, *Inextendibility of spacetimes and Lorentzian length spaces*, arXiv:1804.10423 [math.DG], CBS.

Z. Li, D. F. Scharler, H.-P. Schröcker, *Factorization Results for Left Polynomials in Some Associative Real Algebras: State of the Art, Applications, and Open Questions*, arXiv:1803.06194 [math.RA], CBS.

M. Kunzinger, C. Sämann, *Lorentzian length spaces*, arXiv:1711.08990 [math.DG], CBS.

T. Makino, *On slowly rotating axisymmetric solutions of the Einstein-Euler equations*, Journal of Mathematical Physics 59, 102502(2018), DOI: https://doi.org/10.1063/1.5026133, arXiv:1705.07392 [math.AP], CBS.

H. Barzegar, P. T. Chruśiel, L. Nguyen, *On the total mass of asymptotically hyperbolic manifolds*, arXiv:1812.03924 [gr-qc], CBS.

L. Andersson, A. Y. Burtscher, *On the Asymptotic Behavior of Static Perfect Fluids*, https://link.springer.com/article/10.1007/s00023-018-00758-z, arXiv:1801.06614 [gr-qc], JRF.

List of all visitors in 2018

763 scientists have visited the ESI in 2018.

The following codes indicate the association of visitors with specific ESI activities:

AHM = Mathematical Aspects of Physical Oceanography
BTZ = Geometric Correspondences of Gauge Theories
CGP = Mathematical Challenges of Structured Function Systems
CMF = Advances in Chemical Reaction Network Theory
CSR = Bivariant K-theory in geometry and physics
DFS = New Trends in the Variational Modeling of Failure Phenomena
DKB = ECAM State-of-the Art Workshop: Large Scale activated Event Simulations
GNB = Rigidity and Flexibility of Geometric Structures
IS = Individual Scientists
JRF = Junior Research Fellow
GLO = Analysis and CR Geometry
MSC = Quantum Paths
OST = Matrix Models for Noncommutative Geometry and String Theory
PSH = Numerical Analysis of Complex PDE Models in the Sciences
RIT = Research in Teams
SAB = Scientific Advisory Board
SRF = Senior Research Fellows
WTW = Moonshine

Abanin Dmitry, U of Geneva; 08.04.2018 - 16.04.2018, MSC
Abdulle Assyr, EPFL, Lausanne; 25.06.2018 - 04.07.2018, PSH
Abrashkin Anatoly, National Research U, Nizhny Novgorod; 09.03.2018 - 22.03.2018, AHM
Adachi Masanori, Shizuoka U; 08.12.2018 - 15.12.2018, GLO
Adamer Michael, U of Oxford; 13.10.2018 - 19.10.2018, CMF
Agazzi Andrea, Duke University, Durham, North Carolina; 14.10.2018 - 19.10.2018, CMF
Ahmad Rashid, ; 09.07.2018 - 13.07.2018, OST
Ahmadinezhad Hamid, Loughborough U; 01.08.2018 - 31.08.2018, RIT
Akahori Takao, U Hyogo; 06.12.2018 - 16.12.2018, GLO
Alba Vincenzo, SISSA, Trieste; 08.04.2018 - 27.04.2018, MSC
Alexandrov Sergey, U Montpellier II; 09.09.2018 - 15.09.2018, WTW
Almi Stefano, TU Munich; 19.08.2018 - 24.08.2018, DFS
Anagiannis Vassilis, U of Amsterdam; 10.09.2018 - 14.09.2018, WTW
Anderson David, U of Wisconsin-Madison; 13.10.2018 - 21.10.2018, CMF
Andersson Lars, AEI Postdam; 02.08.2018 - 07.08.2018, IS

Antoniĉ Nenad, U of Zagreb; 19.08.2018 - 24.08.2018, DFS
Arici Francesca, MPI, Leipzig; 21.11.2018 - 28.11.2018, CSR
Arbic Brian, U of Michigan; 10.03.2018 - 16.03.2018, AHM; 18.03.2018 - 21.03.2018, AHM
Aricheta Victor Manuel, Emory U, Atlanta; 09.09.2018 - 15.09.2018, WTW
Asano Yuhma, KEK, Tsukuba; 08.07.2018 - 15.07.2018, OST
Aspri Andrea, RICAM, Linz; 25.06.2018 - 29.06.2018, PSH
Aufféves Alexia, Institut Neel-CNRS, Grenoble; 28.10.2018 - 30.10.2018, IS
Austad Are, NTNU Trondheim; 18.11.2018 - 30.11.2018, CSR
Avohou Remi Cocou , U Jerusalem; 23.09.2018 - 29.09.2018, GNB
Azzali Sara, U Potsdam; 18.11.2018 - 01.12.2018, CSR
Bach Annika, TU Munich; 2018.08.2018 - 24.08.2018, DFS
Bachmayr Markus, U Bonn; 10.06.2018 - 15.06.2018, PSH
Bandara Lashi, U Potsdam; 03.11.2018 - 11.11.2018, CSR
Banlaki Andreas, TU Vienna; 10.09.2018 - 14.09.2018, WTW
Banuls Maria Carmen, MPI, Garching ; 13.05.2018 - 25.05.2018, MSC
Bartels Sören, U of Freiburg; 15.07.2018 - 20.07.2018, PSH
Bastianello Alvise, SISSA, Trieste; 27.05.2018 - 02.06.2018, MSC
Basu Biswajit, Trinity College Dublin; 11.03.2018 - 15.03.2018, AHM
Baum Paul Frank, Pennsylvania State U, University Park; 10.11.2018 - 14.11.2018, CSR
Bebendorf Mario, U of Bayreuth; 11.06.2018 - 15.06.2018, PSH
Beirao da Veiga Lourenco, U di Milano-Bicocca; 15.07.2018 - 20.07.2018, PSH
Belz Sandro, TU Munich; 19.08.2018 - 24.08.2018, DFS
Beneish Lea, Emory U, Atlanta; 09.09.2018 - 15.09.2018, WTW
Berenstein David, UC, Santa Barbara; 06.07.2018 - 14.07.2018, OST
Berges Jürgen, U Heidelberg; 08.04.2018 - 12.04.2018, MSC
Bergshoeff Eric, U of Groningen; 03.01.2018 - 03.03.2018, SRF
Berhanu Shiferaw, Temple U, Philadelphia; 10.12.2018 - 15.12.2018, GLO
Bernard Denis, École Normale Superieure, Paris; 08.04.2018 - 13.04.2018, MSC; 16.06.2018 - 18.06.2018, SAB
Bernkopf Maximilian, U Vienna; 11.06.2018 - 15.06.2018, PSH
Beron-Vera Francisco, U of Miami; 05.03.2018 - 17.03.2018, AHM
Bertini Bruno, U of Ljubljana; 08.04.2018 - 21.04.2018, MSC; 28.05.2018 - 02.06.2018, MSC
Bertoluzza Silvia, CNR Imati "Enrico Magenes", Pavia; 07.07.2018 - 21.07.2018, PSH
Bertrand Fleurianne, U Duisburg-Essen; 15.07.2018 - 20.07.2018, PSH
Bertrand Florian, American U of Beirut; 09.12.2018 - 15.12.2018, GLO
Bhaseen Miraculous, King's College London; 20.05.2018 - 26.05.2018, MSC
Biard Severine, U of Iceland, Reykjavik; 09.12.2018 - 15.12.2018, GLO
Bibbona Enrico, Politecnico di Torino; 14.10.2018 - 19.10.2018, CMF
Bickel Kelly, Bucknell U; 18.03.2018 - 24.03.2018, CGP
Binev Peter, U of South Carolina; 16.07.2018 - 26.07.2018, PSH
Boffi Daniele, U of Pavia; 15.07.2018 - 20.07.2018, PSH
Börm Steffen, U Kiel; 10.06.2018 - 15.06.2018, PSH
Bolhuis Peter, U of Amsterdam; 30.09.2018 - 03.10.2018, DKB
Bonelli Giulio, SISSA, Trieste; 26.08.2018 - 06.09.2018, BTZ
Bonizzoni Francesca, U of Vienna; 11.06.2018 - 15.06.2018, PSH; 25.06.2018 - 29.06.2018, PSH; 16.07.2018 - 20.07.2018, PSH
Borcea Ciprian, Rider U, Lawrenceville; 23.09.2018 - 29.09.2018, GNB
Borichev Alexander, Aix-Marseille U; 18.03.2018 - 23.03.2018, CGP
Boros Balázs, U Vienna; 14.10.2018 - 19.10.2018, CMF

Bourne Chris, Tohoku U; 14.11.2018 - 30.11.2018, CSR

Branicki Michal, U of Edinburgh; 12.03.2018 - 17.03.2018, AHM; 24.06.2018 - 27.06.2018, PSH

Brazda Katharina, U Vienna; 12.03.2018 - 16.03.2018, AHM; 20.08.2018 - 24.08.2018, DFS

Brenner Susanne, Louisiana State U; 23.06.2018 - 01.07.2018, PSH

Bressan Alberto, Penn State U; 12.02.2018 - 19.02.2018, AHM

Bressan Andrea, U of Oslo; 15.07.2018 - 22.07.2018, PSH

Brezzi Franco, IMATI-CNR Pavia; 15.07.2018 - 20.07.2018, PSH

Bricmont Jean, U Catholique de Louvain; 28.10.2018 - 01.11.2018, IS

Brinkschulte Judith, U of Leipzig; 09.12.2018 - 12.12.2018, GLO

Broström Göran, U of Gothenburg; 06.03.2018 - 15.03.2018, AHM

Brünnig Michael, Bergische U Wuppertal; 10.12.2018 - 15.12.2018, GLO

Bruzzo Ugo, SISSA, Trieste; 26.08.2018 - 05.09.2018, BTZ

Buffa Annalisa, EPFL, Lausanne; 15.07.2018 - 20.07.2018, PSH

Burde Dietrich, U Vienna; 23.04.2018 - 27.04.2018, IS

Burić Maja, U of Belgrade; 08.07.2018 - 14.07.2018, OST

Burman Erik, U College London; 25.06.2018 - 29.06.2018, PSH; 15.07.2018 - 19.07.2018, PSH

Bužančić Marin, U of Zagreb; 19.08.2018 - 24.08.2018, DFS

Calabrese Pasquale, SISSA, Trieste; 08.04.2018 - 14.04.2018, MSC

Caćić Branimir Josip, U of New Brunswick, Fredericton; 06.11.2018 - 10.11.2018, CSR

Campos Yuste Manuel, IFT, Madrid; 13.05.2018 - 19.05.2018, MSC

Cao Yalong, U of Oxford; 26.08.2018 - 08.09.2018, BTZ

Capco Jose, JKU Linz; 24.09.2018 - 28.09.2018, GNB

Cappelletti Daniele, ETH Zurich; 14.10.2018 - 19.10.2018, CMF

Cappelli Andrea, INFN, Firenze ; 09.04.2018 - 13.04.2018, MSC; 29.04.2018 - 05.05.2018, MSC

Carey Alan L., ANU Canberra; 03.11.2018 - 16.11.2018, CSR

Carioni Marcello, KFU Graz; 19.08.2018 - 24.08.2018, DFS

Carnahan Scott, U of Tsukuba; 10.09.2018 - 15.09.2018, WTW

Carnevale Angela, Bielefeld U; 28.07.2018 - 30.11.2018, JRF

Carow-Watamura Ursula, Tohoku U; 07.07.2018 - 15.07.2018, OST

Carstensen Carsten, Humboldt U; 01.08.2018 - 13.08.2018, PSH

Castro Alvaredo Eulalia Amparo, U of London; 15.04.2018 - 22.04.2018, MSC; 14.05.2018 - 19.05.2018, MSC

Caux Jean-Sébastien, U of Amsterdam; 07.04.2018 - 13.04.2018, MSC

Cavaleri Matteo, U "Degli Studi Niccolo" Rome; 15.07.2018 - 15.09.2018, JRF

Ceriotti Michele, Ecole Polytechnique Federale Lausanne; 30.09.2018 - 02.10.2018, DKB

Chabchoub Amin, U of Sydney; 01.02.2018 - 09.02.2018, AHM

Chandrabose Selvaraj, Masaryk U, Brno; 30.09.2018 - 03.10.2018, DKB

Carina Maria, U Vienna; 19.03.2018 - 23.03.2018, CGP

Chattopadhyaya Aradhita, Indian Institute of Science Bangalore; 07.09.2018 - 17.09.2018, WTW

Chatzistavrakidis Athanasios, Rudjer Boskovic Institute, Zagreb; 08.07.2018 - 14.07.2018, OST

Cheltsov Ivan, U of Edinburgh; 01.08.2018 - 31.08.2018, RIT

Chen Zhiming, Chinese Academy of Sciense, Beijing; 24.06.2018 - 30.06.2018, PSH; 15.07.2018 - 21.07.2018, PSH

Chinni Gregorio, U Vienna; 10.12.2018 - 14.12.2018, GLO

Chiocchetta Alessio, U of Colonge; 27.05.2018 - 01.06.2018, MSC

Chodera John D., Memorial Sloan Kering Cancer Center, New York; 30.09.2018 - 03.10.2018, DKB

Chowdhury Abhishek, TU Vienna; 10.09.2018 - 14.09.2018, WTW

Christensen Kai Håkon, Norwegian Metrological Institute; 04.03.2018 - 08.03.2018, AHM

Christensen Ole, TU of Denmark; 18.03.2018 - 24.03.2018, CGP

Chung Eric, The Chinese U of Hong Kong; 24.06.2018 - 30.06.2018, PSH
Cirac J. Ignacio, MPI, Garching; 08.04.2018 - 11.04.2018, MSC
Cirak Fehmi, U of Cambridge; 11.07.2018 - 20.07.2018, PSH
Clinch Katharine, U of Tokyo; 23.09.2018 - 28.09.2018, GNB
Cockburn Julio B., U od Minnesota; 15.07.2018 - 21.07.2018, PSH
Collura Mario, U Oxford; 27.05.2018 - 03.06.2018, MSC
Compelli Alan, Dublin Institute of Technology (DIT); 11.03.2018 - 17.03.2018, AHM
Congreve Scott, U Vienna; 25.06.2018 - 17.08.2018, OSH
Conrad Tim, Freie U Berlin; 01.10.2018 - 03.10.2018, DKB
Conradi Carsten, HTW Berlin; 14.10.2018 - 19.10.2018, CMF
Constantin Adrian, U Vienna; 22.01.2018 - 23.03.2018, AHM
Conti Costanza, U di Firenze; 18.03.2018 - 22.03.2018, CGP
Contreras Tejada Patricia, ICMAT, Madrid; 16.09.2018 - 22.09.2018, IS
Cordaro Paulo Domingos, U Sao Paulo; 08.12.2018 - 15.12.2018, GLO
Cotronei Mariantonia, U Mediterranea di Reggio Calabria (DIIES); 18.03.2018 - 23.03.2018, CGP
Craciun Gheorghe, U of Wisconsin-Madison; 14.10.2018 - 23.10.2018, CMF
Creutzig Thomas, U of Alberta, Edmonton; 09.09.2018 - 15.09.2018, WTW
Crowdy Darren, Imperial College London; 14.03.2018 - 17.03.2018, AHM
Cruickshank James, NUI Galway; 23.09.2018 - 29.09.2018, GNB
Cuntz Joachim, U Münster; 12.11.2018 - 16.11.2018, CSR
Curiel Erik, LMU, Munich; 28.10.2018 - 30.10.2018, IS
Curry Sean, UC San Diego; 10.12.2018 - 16.12.2018, GLO
Cvetic Miriam, U of Pennsylvania; 17.06.2018 - 18.06.2018, SAB
Dabrowski Ludwik, SISSA Trieste; 18.11.2018 - 30.11.2018, CSR
Dahmen Wolfgang, U of South Carolina; 10.06.2018 - 15.06.2018, PSH
Dalla Torre Emanuele, Bar-Ilan U, Israel; 09.04.2018 - 13.04.2018, MSC
Dalmonte Marcello, ICTP, Trieste; 07.05.2018 - 11.05.2018, MSC
D'Angelo John P., University of Illinois, Urbana; 09.12.2018 - 15.12.2018, GLO
D'Arcangelo Mauro, U of Nottingham; 08.07.2018 - 13.07.2018, OST
David Justin, Indian Institute of Science, Bangalore; 09.09.2018 - 15.09.2018, WTW
Davoli Elisa, U Vienna; 20.08.2018 - 24.08.2018, DFS
De Bernardis Daniele, TU Vienna; 13.04.2018 - 09.04.2018, MSC
Defenu Nicoló, Heidelberg U; 27.05.2018 - 31.05.2018, MSC
Deguchi Tetsuo, Ochanomizu U; 24.04.2018 - 04.05.2018, MSC
Dekimpe Karel, KU Leuven; 22.04.2018 - 27.04.2018, IS
Dolgov Sergey, U of Bath; 10.06.2018 - 29.06.2018, PSH
Dellar Paul, Corpos Christi College, Oxford; 20.01.2018 - 28.01.2018, AHM; 12.03.2018 - 24.03.2018, AHM
Della Sala Giuseppe, AUB Beirut; 09.12.2018 - 14.12.2018, GLO
De Luca Andrea, U of Oxford; 27.05.2018 - 01.06.2018, MSC
De Luca Lucia, SISSA, Trieste; 19.08.2018 - 26.08.2018, DFS
Demkowicz Leszek Feliks, The U of Texas at Austin; 10.06.2018 - 15.06.2018, PSH
Demler Eugene; Harvard U; 08.04.2018 - 12.04.2018, MSC
De Nardis Jacopo, ENS, Paris; 10.04.2018 - 19.04.2018, MSC; 27.05.2018 - 03.06.2018, MSC
De Nitti Nicola, U of Bari Aldo Moro; 20.08.2018 - 24.08.2018, DFS
Dewar Sean, U Lancaster; 23.09.2018 - 28.09.2018, GNB
Diaz-Leines Grisell, Ruhr-Universität Bochum; 30.09.2018 - 04.10.2018, DKB
Diehl Sebastian, U zu Köln; 24.04.2018 - 29.04.2018, MSC
Diesse Marc, HS Heilbronn; 23.09.2018 - 28.09.2018, GNB

Dong Guozhi, Humbold U of Berlin; 20.06.2018 - 01.07.2018, PSH

Dóra Balázs, Budapest U for Technological Economics; 26.04.2018 - 27.04.2018, MSC; 03.05.2018 - 04.05.2018, MSC

Doyon Benjamin, King's College London; 15.04.2018 - 19.04.2018, MSC

Duarte-Guerreiro Tiego, Loughborough U; 23.09.2018 - 28.09.2018, GNB

Dubail Jerome, U of Lorraine, Nancy ; 15.04.2018 - 28.04.2018, MSC

Duncan John, Emory U, Atlanta; 09.09.2018 - 14.09.2018, WTW

Duruk Mutlubas Nilay, Sabanci U, Istanbul; 16.02.2018 - 21.02.2018, AHM

Dym Harry, The Weizmann Institute; 18.03.2018 - 22.03.2018, CGP

Ebenfelt Peter, UC San Diego; 10.12.2018 - 15.12.2018, GLO

Echterhoff Siegfried, U Münster; 03.11.2018 - 10.11.2018, CSR

Edholm Luke, U of Michigan, Ann Arbor; 08.12.2018 - 15.12.2018, GLO

Efendiev Yalchin, Texas A&M U; 24.06.2018 - 27.06.2018, PSH

Eisert Jens, FU Berlin; 08.04.2018 - 10.04.2018, MSC

Elbrächter Dennis, U of Vienna; 11.06.2018 - 15.06.2018, PSH

Engquist Bjorn, U of Texas at Austin ; 10.06.2018 - 13.06.2018, PSH; 24.06.2018 - 29.06.2018, PSH

Erkinger David, U of Vienna; 27.08.2018 - 07.09.2018, BTZ

Ern Alexandre, ENPC, Paris; 15.07.2018 - 27.07.2018, PSH

Essler Fabian, U Oxford; 08.04.2018 - 05.05.2018, MSC; 27.05.2018 - 01.06.2018, MSC

Evans John, U Colorado, Boulder; 15.07.2018 - 21.07.2018, PSH

Everaers Ralf, ENS Lyon; 30.09.2018 - 02.10.2018, DKB

Evertz Hans Gerd, TU Graz; 09.04.2018 - 13.04.2018, MSC; 17.04.2018 - 20.04.2018, MSC

Fagotti Maurizio, LPTMS, CNRS Orsay; 08.04.2018 - 20.04.2018, MSC; 27.05.2018 - 01.06.2018, MSC

Fanzon Silvio, Karl Franzens U, Graz; 19.08.2018 - 24.08.2018, DFS

Farazmand Mohammad, MIT, Cambridge; 10.03.2018 - 18.03.2018, AHM

Fasola Nadir, SISSA, Trieste; 26.08.2018 - 07.09.2018, BTZ

Faulhuber Markus, NTNU Trondheim; 18.03.2018 - 23.03.2018, CGP

Faustmann Markus, TU Vienna; 11.06.2018 - 16.06.2018, PSH; 25.06.2018 - 29.06.2018, PSH; 17.07.2018 - 20.07.2018, PSH

Fazio Rosario, ICTP, Trieste; 09.04.2018 - 13.04.2018, MSC

Fearn Sam, Durham U; 08.09.2018 - 17.09.2018, WTW

Feichtinger Hans, U Vienna; 19.03.2018 - 23.03.2018, CGP

Feischl Michael, KIT, Karlsruhe; 11.06.2018 - 17.06.2018, PSH; 24.06.2018 - 01.07.2018, PSH

Feliu Elisenda, U of Copenhagen; 15.10.2018 - 19.10.2018, CMF

Fendley Paul, Oxford U; 22.04.2018 - 27.04.2018, MSC

Ferlaino Francesca, U of Innsbruck; 09.04.2018 - 10.04.2018, MSC

Ferrari Frank, U Libre de Bruxelles (ULB); 08.07.2018 - 14.07.2018, OST

Ferreira Rita, KAUST, Thuwal; 19.08.2018 - 25.08.2018, DFS

Fidkowski Lukasz, U of Washington; 08.04.2018 - 14.04.2018, MSC

Filbet Francis, U of Toulouse; 29.07.2018 - 12.08.2018, SRF

Filev Veselin, IMI, BAS, Sofia; 08.07.2018 - 14.07.2018, OST

Fischer Julian, IST Austria; 20.08.2018 - 24.08.2018, DFS

Flamm Christoph, U of Vienna; 15.10.2018 - 19.10.2018, CMF

Flörchinger Stefan, U Heidelberg; 15.04.2018 - 24.04.2018, MSC; 30.06.2018 - 04.06.2018, MSC

Fonseca Irene, Carnegie Mellon U, Pittsburgh; 19.08.2018 - 23.08.2018, DFS

Fornaess John Erik, NTNU Trondheim; 10.12.2018 - 14.12.2018, GLO

Forstneric Franc, U of Lubljana; 10.12.2018 - 14.12.2018, GLO

Frahm Holger, Leibniz U Hannover; 01.05.2018 - 10.05.2018, MSC

Francfort Gilles, U Paris 13; 19.08.2018 - 24.08.2018, DFS

Frechette Layne, U of California, Berkeley ; 09.04.2018 - 12.05.2018, JRF

Fredenhagen Stefan, U Vienna; 09.07.2018 - 09.07.2018, OST; 10.09.2018 - 14.09.2018, WTW

Friedrich Helmut, MPI Potsdam; 24.11.2018 - 01.12.2018, IS

Friedrich Manuel, WWU Münster; 20.08.2018 - 24.08.2018, DFS

Fu Siqi, Rutgers U, Camden; 09.12.2018 - 15.12.2018, GLO

Fukuma Masafumi, Kyoto U; 07.07.2018 - 14.07.2018, OST

Funke Jens, Durham U; 09.09.2018 - 15.09.2018, WTW

Fürdös Stefan, Masaryk U, Brno; 12.10.2018 - 14.12.2018, GLO

Galitskiy Victor, U of Maryland; 13.05.2018 - 21.05.2018, MSC; 27.05.2018 - 01.06.2018, MSC

Gallagher Anne-Katrin, Oklahoma State U, Stillwater; 09.12.2018 - 14.12.2018, GLO

Gallet Matteo, RISC, JKU Linz; 24.09.2018 - 28.09.2018, GNB

Gambassi Andrea, SISSA, Trieste; 18.04.2018 - 29.04.2018, MSC

Ganahl Martin, Perimeter Institute, Waterloo; 16.04.2018 - 04.05.2018, MSC

Gantner Gregor, TU Vienna; 16.07.2018 - 20.07.2018, PSH

Garrahan Juan P., U of Nottingham; 16.04.2018 - 19.04.2018, MSC

Gasenzer Thomas, U Heidelberg; 11.04.2018 - 20.04.2018, MSC

Gasull Armengol, U Autónoma de Barcelona; 15.07.2018 - 02.08.2018, RiT

Gayral Victor, U of Reims; 25.11.2018 - 30.11.2018, CSR

Gawedzki Krzysztof, ENS, Lyon; 26.11.2018 - 30.11.2018, CSR

Gedicke Joscha, U Vienna; 11.06.2018 - 17.08.2018, PSH

Gemünden Thomas, ETH Zurich; 09.09.2018 - 14.09.2018, WTW

Geyer Anna, Delft U of Technology; 11.02.2018 - 23.02.2018, AHM; 01.07.2018 - 31.07.2018, RiT

Giacomini Alessandro, U degli Studi di Brescia; 19.08.2018 - 24.08.2018, DFS

Giamarchi Thierry, U of Geneva; 29.04.2018 - 02.05.2018, MSC

Giannakis Dimitrios, New York U; 11.03.2018 - 16.03.2018, AHM; 24.06.2018 - 28.06.2018, PSH

Giannelli Carlotta, U of Florence; 15.07.2018 - 20.07.2018, PSH

Glaser Lisa, Radboud-U Nijmegen; 08.07.2018 - 13.07.2018, OST

Gladbach Peter, U of Leipzig; 19.08.2018 - 24.08.2018, DFS

Goffeng Magnus, U of Gothenburg, Chalmers; 27.11.2018 - 01.12.2018, CSR

Gopalakrishnan Jay, Portland State U; 14.07.2018 - 18.07.2018, PSH

Goremykina Anna, U of Geneva; 09.04.2018 - 13.04.2018, MSC

Graf von Bothmer Hans-Christian, U of Hamburg; 24.09.2018 - 28.09.2018, GNB

Grasegger Georg, RICAM Linz; 24.09.2018 - 28.09.2018, GNB

Gritsev Vladimir, U of Amsterdam; 20.05.2018 - 02.06.2018, MSC

Gröchenig Karlheinz, U Vienna; 19.03.2018 - 24.03.2018, CGP

Groha Stefan, U of Oxford; 27.05.2018 - 02.06.2018, MSC

Grohs Philipp, U Vienna, 19.03.2018 - 23.03.2018, CGP; 11.06.2018 - 15.06.2019, PSH

Grosse Harald, U Vienna; 27.08.2018 - 07.09.2018, BTZ; 05.11.2018 - 30.11.2018, CSR

Grumiller Daniel, TU Vienna; 24.04.2018 - 24.04.2018, MSC; 10.09.2018 - 14.09.2018, WTW

Guest Simon, U Cambridge; 23.09.2018 - 26.09.2018, GNB

Gupta Purvi, Rutgers U, New Brunswick; 09.12.2018 - 15.12.2018, GLO

Gupta Rajesh Kumar, King's College London; 09.09.2018 - 12.09.2018, WTW

Gurarie Victor, U of Colorado, Boulder; 17.04.2018 - 02.05.2018, MSC

Gutleb Timon Salar, U Vienna; 09.07.2018 - 13.07.2018, OST

Hadzibabic Zoran, U of Cambridge; 11.04.2018 - 22.04.2018, MSC

Haimi Antti, Acoustics Research Institute, Vienna; 19.03.2018 - 23.03.2018, CGP

Haller George, ETH Zurich; 11.03.2018 - 16.03.2018, AHM

Haller Stefan, U Vienna; 13.11.2018 - 30.11.2018, CSR

Hanada Masanori, U of Colorado; 10.07.2018 - 15.07.2018, OST
Hantal György, U Vienna; 01.10.2018 - 03.10.2018, DKB
Harar Pavol, U of Vienna & Brno U of Technology; 19.03.2018 - 22.03.2018, CGP
Harbrecht Helmut, U Basel; 10.06.2018 - 15.06.2018, PSH
Harrop-Griffiths Benjamin, New York U; 05.03.2018 - 16.03.2018, AHM
Harz Tobias, Bergische U Wuppertal; 08.12.2018 - 14.12.2018, GLO
Haslinger Friedrich, U Vienna; 19.03.2018 - 21.03.2018, CGP; 10.12.2018 - 14.12.2018, GLO
Haslinger Philipp, TU Vienna; 09.04.2018 - 08.06.2018, MSC
Hausel Tamás, IST Austria; 04.09.2018 - 05.09.2018, BTZ
Hayashi Shin, AIST Tohoku U; 18.11.2018 - 01.12.2018, CSR
Haziot Susanna, U Vienna; 20.01.2018 - 23.03.2018, AHM
He Zeyuan, U of Cambridge; 23.09.2018 - 01.10.2018, GNB
Heidrich-Meisner Fabian, U of Göttingen; 26.05.2018 - 02.06.2018, MSC
Helmer Martin, U of Copenhagen; 14.10.2018 - 20.10.2018, CMF
Henry David, U College Cork; 21.01.2018 - 28.01.2018, AHM; 04.02.2018 - 16.02.2018, AHM; 08.03.2018 - 15.03.2018, AHM
Heyl Markus, MPI-PKS, Dresden; 14.05.2018 - 16.05.2018, MSC
Higson Nigel, Pennsylvania State U, University Park; 17.11.2018 - 24.11.2018, CSR
Hilsum Michel, CNRS Paris; 18.11.2018 - 01.12.2018, CSR
Hiptmair Ralf, ETH Zurich; 01.07.2018 - 08.07.2018, PSH; 13.07.2018 - 28.07.2018, PSH
Ho Tin-Lun, The Ohio State U; 07.04.2018 - 14.04.2018, MSC
Hoang Viet Ha, Nanyang TU, Singapore; 24.06.2018 - 07.07.2018, PSH
Hock Alexander, WWU Münster; 01.12.2018 - 08.12.2018, CSR
Hofbauer Franz, U Vienna; 15.10.2018 - 19.10.2018, CMF
Hofreither Clemens, JKU Linz; 10.06.2018 - 15.06.2018, PSH
Höhn Gerald, Kansas State U; 09.09.2018 - 15.09.2018, WTW
Holden Helge, Norwegian U of Science and Technology, Trondheim; 16.06.2018 - 18.06.2018, SAB
Hoppe Jens, Royal Institute of Technology, Stockholm; 08.07.2018 -15.07.2018
Hoque SK Jahnur, The Institute of Mathematical Science, Chennai, India; 21.06.2018 - 07.07.2018, IS
Hou Thomas, Caltech, Pasadena; 24.06.2018 - 02.07.2018, PSH
Hounie Jorge, U Federal de Sao Carlos; 09.12.2018 - 15.12.2018, GLO
Hsiao Chin-Yu, Academia Sinica, Taipei; 10.12.2018 - 15.12.2018, GLO
Huang De, Caltech, Pasadena; 24.06.2018 - 02.07.2018, PSH
Huber Marcus, IQOQI Vienna; 09.04.2018 - 08.06.2018, MSC
Hummer Gerhard, MPI, Frankfurt; 01.10.2018 - 03.10.2018, DKB; 28.10.2018 - 30.10.2018, IS
Huybrechts Daniel, U Bonn; 16.06.2018 - 18.06.2018, SAB
Ide Kayo, U of Maryland; 11.03.2018 - 17.03.2018, AHM
Imbert-Gerard Lise-Marie, U of Maryland; 24.06.2018 - 08.07.2018, PSH; 13.07.2018 - 21.07.2018, PSH
Immirzi Giorgio, U di Perugia; 08.07.2018 - 14.07.2018, OST
Innerbichler Max, U Vienna; 01.10.2018 - 03.10.2018, DKB
Ishiki Goro, U of Tsukuba; 09.07.2018 - 14.07.2018, OST
Ivanov Grigory, EPFL, Lausanne; 22.09.2018 - 28.09.2018, GNB
Ivanov Rossen, Dublin Institute of Technology; 31.01.2018 - 04.02.2018, AHM; 14.03.2018 - 24.03.2018, AHM
Izmestiev Ivan, U of Fribourg; 23.09.2018 - 05.10.2018, GNB
Jackson Bill, Queen Mary U, London; 23.09.2018 - 28.09.2018, GNB
Jaming Philippe, U de Bordeaux; 18.03.2018 - 21.03.2018, CGP
Janos Pavel, Masaryk U, Brno; 01.10.2018 - 03.10.2018, DKB Jesenko Martin, Albert-Ludwigs-U,

Freiburg; 19.08.2018 - 24.08.2018, DFS

Jetter Kurt, U Hohenheim; 18.03.2018 - 24.03.2018, CGP

Johansson Jimmy, U of Gothenburg; 09.12.2018 - 15.12.2018, GLO

Johnson Robin S., Newcastle U; 23.01.2018 - 15.03.2018, AHM

Johnston Matthew, San José State U; 14.10.2018 - 20.10.2018, CMF

Jordan Tibor, Eötvös U, Budapest; 22.09.2018 - 28.09.2018, GNB

Joshi Badal, California State U San Marcos; 14.10.2018 - 19.10.2018, CMF

Julg Pierre, U d'Orléans; 17.11.2018 - 01.12.2018, CSR

Jüttler Bert, JKU Linz; 16.07.2018 - 20.07.2018, PSH

Kaad Jens, U Radboud, Nijmegen; 19.11.2018 - 24.11.2018, CSR

Kaan Ekin, Bogazigi U, Istanbul; 26.08.2018 - 09.09.2018, BTZ

Kahl Gerhard, TU Vienna; 01.10.2018 - 03.10.2018, DKB

Kaltenbacher Barbara, Alpen-Adria U Klagenfurt; 24.06.2018 - 29.06.2018, PSH

Kanschat Guido, U Heidelberg; 10.06.2018 - 17.06.2018, PSH; 24.06.2018 - 22.07.2018, PSH

Kapidani Bernard, TU Vienna; 26.06.2018 - 29.06.2018, PSH

Karabali Dimitra, CUNY; 08.07.2018 - 15.07.2018, OST

Karczmarek Joanna, U Vancouver; 08.07.2018 - 14.07.2018, OST

Karpenkov Oleg, U of Liverpool; 23.09.2018 - 28.09.2018, GNB

Karrasch Daniel, TU Munich; 12.03.2018 - 16.03.2018, AHM

Kastis Elefherios, U Lancaster ; 23.09.2018 - 29.09.2018, GNB

Kastner Michael, National Institute for Theoretical Physics, Stellenbosch; 15.04.2018 - 27.04.2018, MSC

Kawai Hikaru, Kyoto U; 08.07.2018 - 14.07.2018, OST

Kazeev Vladimir, Stanford U; 09.06.2018 - 16.06.2018, PSH; 23.06.2018 - 29.06.2018, PSH

Kellendonk Johannes, U Lyon 1; 25.11.2018 - 30.11.2018, CSR

Keller Bettina, Freie U Berlin; 30.09.2018 - 03.10.2018, DKB

Kertels Fabian, Albert Ludwigs U Freiburg; 09.09.2018 - 15.09.2018, WTW

Khaqan Maryam, Emory U, Atlanta ; 09.09.2018 - 16.09.2018, WTW

Kholmatov Shokhrukh, U Vienna; 20.08.2018 - 24.08.2018, DFS

Khusnutdinova Karima, Loughborough U; 11.03.2018 - 23.03.2018, AHM

Kim Jinsu, UCalifornia, Irvine ; 14.10.2018 - 19.10.2018, CMF

Kimura Taro, Keio U, Yokohama; 17.08.2018 - 31.08.2018, BTZ

Klemm Albrecht, U Bonn; 09.09.2018 - 15.09.2018, WTW

Khoromskij Boris, MPI, Leipzig; 12.06.2018 - 15.06.2018, PSH

Kluczek Mateusz, U College Cork; 25.02.2018 - 04.03.2018, AHM

Klümper Andreas, Bergische U Wuppertal; 21.05.2018 - 25.05.2018, MSC

Knapp Johanna, TU Vienna; 03.09.2018 - 07.09.2018, BTZ

Knees Dorothee, U of Kassel; 19.08.2018 - 24.08.2018, DFS

Knese Gregory E., Washington U, St. Louis ; 18.03.2018 - 24.03.2018, CGP

Köbis Markus, FU Berlin; 14.10.2018 - 19.10.2018, CMF

Konik Robert, Brookhaven National U; 08.04.2018 - 21.04.2018, MSC

Kogelbauer Florian, ETH Zurich; 12.03.2018 - 16.03.2018, AHM

Kolounzakis Mihalis, U of Crete; 16.03.2018 - 24.03.2018, CGP

Koltai Péter, Freie U Berlin; 10.03.2018 - 17.03.2018, AHM

Koppensteiner Sarah, U Vienna; 19.03.2018 - 23.03.2018, CGP;

Kormos Márton, Budapest U of Technology and Economics; 15.04.2018 - 20.04.2018, MSC

Kosiuk Ilona, TU Vienna; 15.10.2018 - 19.10.2018, CMF

Koslowski Tim, UNAM, Mexico City; 09.07.2018 - 13.07.2018, OST

Konstantatou Marina, U of Cambridge; 23.09.2018 - 28.09.2018, GNB

Kool Martijn, Utrecht U; 02.09.2018 - 09.09.2018, BTZ

Koutschan Christoph, RICAM, Austria Academy of Science, Linz; 24.09.2018 - 28.09.2018, GNB

Kovácik Samuel, Dublin Insitute of Advanced Studies; 08.07.2018 - 13.07.2018, OST

Kozcaz Can, Bogazici U, Istanbul; 28.08.2018 - 04.09.2018, BTZ

Kreisbeck Carolin, U Utrecht; 19.08.2018 - 24.08.2018, DFS

Kessner Daniel, EPFL, Lausanne; 11.06.2018 - 14.06.2018, PSH

Kreutz Leonard, U Vienna; 20.08.2018 - 24.08.2018, DFS

KruźiḰ Martin, Czech Academy of Science; 19.08.2018 - 24.08.2018, DFS

Kull Ilya, IQUQI Vienna; 09.04.2018 - 13.04.2018, MSC

Kunštek Petar, U of Zagreb; 19.08.2018 - 24.08.2018, DFS

Kürkcüoglu Seckin, Middle East TU (METU), Ankara; 08.07.2018 - 15.07.2018, OST

Kusakabe Yuta, Osaka U; 09.12.2018 - 15.12.2018, GLO

Lam Ka Chun (Jeffrey), Caltech, Pasadena; 24.06.2018 - 02.07.2018, PSH

Lamacraft Austen, U of Cambridge; 20.05.2018 - 01.06.2018, MSC

Lamel Bernhard, U Vienna; 10.12.2018 - 14.12.2018, GLO

Landi Giovanni, U of Trieste; 10.11.2018 - 20.11.2018, CSR

Langer Ulrich, JKU Linz; 16.07.2018 - 20.07.2018, PSH

Larose Ryan, Michigan State U; 16.09.2018 - 22.09.2018, IS

Läuchli Andreas, U Innsbruck; 08.04.2018 - 11.04.2018, MSC

Laurent Christine, CNRS, Institut Fourier, Grenoble; 09.12.2018 - 14.12.2018, GLO

Lazaroiu Calin, IBS-CGP, Pohang; 02.07.2018 - 07.07.2018, IS

Lazzaroni Giuliano, U of Naples "Federico II"; 19.08.2018 - 25.08.2018, DFS

Lebl Jiri, Oklahoma State U, Stillwater; 09.12.2018 - 15.12.2018, GLO

Lee Gihyun, Seoul National U; 18.11.2018 - 30.11.2018, CSR

Legersky Jan, RISC JKU Linz; 24.09.2018 - 28.09.2018, GNB Leimkuhler Benedict, U of Edinburgh; 30.09.2018 - 04.10.2018, DKB

Leitold Christian, UC Santa Barbara; 30.09.2018 - 08.10.2018, DKB

Lek-Heng Lim, U of Chicago; 13.06.2018 - 17.06.2018, PSH

Lemeshko Mikhail, IST Austria; 09.04.2018 - 08.06.2018, MSC

Lemvig Jakob, TU Denmark; 18.03.2018 - 22.03.2018, CGP

Leok Melvin, U of California, San Diego; 10.06.2018 - 16.06.2018, PSH

Leoni Giovanni, Carnegie Mellon U, Pittsburgh; 18.08.2018 - 23.08.2018, DFS

Lepori Luca, Laboratorio Gran Sasso L'Aquila ; 27.05.2018 - 30.05.2018, MSC

Lerose Alessio, SISSA, Trieste; 27.05.2018 - 01.06.2018, MSC

Li Guanglian, Imperial College London; 26.06.2018 - 30.06.2018, PSH; 15.07.2018 - 21.07.2018, PSH

Li Xiao, U of Maryland; 20.05.2018 - 02.06.2018, MSC

Li Yingkun, TU Darmstadt; 09.09.2018 - 15.09.2018, WTW

Li Zijia, RICAM Linz; 23.09.2018 - 28.09.2018, GNB

Liany Qi, TU Vienna; 09.04.2018 - 13.04.2018, MSC

Liberti Leo, CNRS LIX, Ecole Polytechnique Palaiseau; 23.09.2018 - 01.10.2018, GNB

Lieb Elliott, Princeton U; 27.10.2018 - 30.10.2018, IS

Liebermeister Wolfram, INRA, Jouy en Josas, France; 14.10.2018 - 20.10.2018, CMF

Liu Pan, U of Cambridge; 19.08.2018 - 30.08.2018, DFS

Locatelli Emanuele, U Vienna; 01.10.2018 - 03.10.2018, DKB

Lockhart Guglielmo, U of Amsterdam; 02.09.2018 - 08.09.2018, BTZ

Lopez Esperanza, Instituto de Fisica Teorica, Madrid; 13.05.2018 - 19.05.2018, MSC

Lopez Quijorna Maria, U Konstanz; 19.03.2018 - 23.03.2018, CGP

Lovas Izabella, Budapest U of Technology and Economics; 07.05.2018 - 09.05.2018, MSC

Lubbes Niels, RICAM, Linz; 24.09.2018 - 28.09.2018, GNB

Lucardesi Ilaria, U de Lorraine, Nancy; 19.08.2018 - 24.08.2018, DFS

Luef Franz, NTNU Trondheim; 12.11.2018 - 30.11.2018, CSR

Lupi Laura, U Vienna; 01.10.2018 - 03.10.2018, DKB

Lyons Tony, Waterford Institute of Technology; 18.02.2018 - 24.02.2018, AHM

Lyu Wenping, RWTH Aachen; 30.09.2018 - 01.10.2018, DKB

Lyubarskii Yurii, Norwegian U of Science and Technology, Trondheim; 19.03.2018 - 28.03.2018, CGP

MacDonald Lachlan, U of Wollongong; 18.11.2018 - 24.11.2018, CSR

MacKernan Donal, University College Dublin ; 01.10.2018 - 03.10.2018, DKB

Mainini Edoardo, U di Genova; 19.08.2018 - 26.08.2018, DFS

Maiwöger Mira, TU Vienna; 09.04.2018 - 13.04.2018, MSC

Mellit Anton, U Vienna; 03.09.2018 - 07.09.2018, BTZ; 10.09.2018 - 14.09.2018, WTW

Mamandur Kidambi Abhiram, TU Vienna ; 10.09.2018 - 14.09.2018, WTW

Manolakos George, National Technical U of Athens; 08.07.2018 - 14.07.2018, OST

Mañosa Víctor, U Politécnica de Catalunya; 01.07.2018 - 31.07.2018, RiT

Manschot Jan, Trinity College Dublin; 02.09.2018 - 06.09.2018, BTZ

Marini Luisa Donatella, U of Pavia; 15.07.2018 - 20.07.2018, PSH

Marino Marcos, U of Geneva; 26.08.2018 - 30.08.2018, BTZ

Marshall David, U Oxford; 28.01.2018 - 02.02.2018, AHM

Martin Calin, U College Cork; 24.01.2018 - 22.03.2018, AHM

Maruyoshi Kazurobu, Seikei U, Tokyo; 02.09.2018 - 08.09.2018, BTZ

Marynets Kateryna, U Vienna; 21.01.2018 - 22.03.2018, AHM

Mascotto Lorenzo, U Vienna; 25.06.2018 - 29.06.2018, PSH; 16.07.2018 - 20.07.2018, PSH

Matias Rodrigo Farinha, U de Coimbra; 09.09.2018 - 15.09.2018, WTW

Matsumoto Kazuko, Tokyo U; 09.12.2018 - 15.12.2018, GLO

Max Christopher, U of Cologne; 18.11.2018 - 30.11.2018, CSR

Mazets Igor, TU Vienna; 09.04.2018 - 13.04.2018, MSC

McNeal Jeffery D., Ohio State U, Columbus; 10.12.2018 - 13.12.2018, GLO

Melching David, U Vienna; 20.08.2018 - 24.08.2018, DFS

Melenk Jens Markus, TU Vienna; 11.06.2018 - 15.08.2018, PSH

Mertens Michael H., U Cologne; 09.09.2018 - 14.09.2018, WTW

Mesland Bram, MPIM Bonn; 04.11.2018 - 30.11.2018, CSR

Meylan Francine, U Fribourg; 09.12.2018 - 15.12.2018, GLO

Micheletti Andrea, U of Rome, Tor Vergata ; 22.09.2018 - 29.09.2018, GNB

Mikkelsen Sophie Emma, U of Southern Denmark, Odense; 18.11.2018 - 23.11.2018, CSR

Mincheva Maya, Northern Illionois U; 13.10.2018 - 20.10.2018, CMF

Minguzzi Anna, CNRS, U Grenoble-Alpes; 28.05.2018 - 01.06.2018, MSC

Minkowski Marcin, U of Vienna; 01.10.2018 - 03.10.2018, DKB

Mir Nordine, U Texas A&M, Qatar; 09.12.2018 - 12.12.2018, GLO

Mironov Andrei, ITEP, Inst. for Theoretical and Experimental Physics, Moscow ; 26.08.2018 - 08.09.2018, BTZ

Mirzaiyan Dehkordi Zahra, Isfahan U of Technology; 30.06.2018 - 01.11.2018, JRF; 26.11.2018 - 30.11.2018, IS

Mitra Aditi, New York U; 12.05.2018 - 25.05.2018, MSC

Mitrea Octavian, Wester U, Ontario ; 09.12.2018 - 15.12.2018, GLO

Moenius Katja, Julius-Maximilians-U Würzburg; 18.03.2018 - 23.03.2018, CGP

Moessner Roderich, MPI, Dresden; 13.04.2018 - 03.05.2018, MSC

Moiola Andrea, U of Pavia; 24.06.2018 - 21.07.2018, PSH

Molchanova Anastasia, Sobolev Institute of Mathematics; 19.08.2018 - 27.08.2018, DFS

Molinet Luc, U of Tours; 16.03.2018 - 22.03.2018, AHM

Monismith Stephan, Stanford U; 13.03.2018 - 22.03.2018, AHM

Monk Peter, U of Delaware; 24.06.2018 - 29.06.2018, PSH

Morandotti Marco, TU Munich; 19.08.2018 - 24.08.2018, DFS Morin Pedro, U Nacional del Litoral, Santa Fe; 15.07.2018 - 20.07.2018, PSH

Moritz Clemens, U Vienna; 01.10.2018 - 03.10.2018, DKB

Morozov Aleksey, ITEP, Inst. for Theoretical and Experimental Physics, Moscow; 26.08.2018 - 09.09.2018, BTZ

Mota Monica Garcia, Simune Atomistic Simulations, San Sebastian, Spain; 01.10.2018 - 03.10.2018, DKB

Müller Andreas, JKU Linz; 23.09.2018 - 27.09.2018, GNB

Müller Christian, TU Vienna; 26.09.2018 - 28.09.2018, GNB

Müller Stefan, U Vienna; 15.10.2018 - 19.10.2018, CMF

Mundilova Klara, U Vienna; 24.09.2018 - 28.09.2018, GNB

Murray Ryan, Penn State U; 11.02.2018 - 17.02.2018, AHM

Murthy Sameer, King's College London; 09.09.2018 - 15.09.2018, WTW

Mussardo Giuseppe, SISSA; 08.04.2018 - 28.04.2018, MSC

Nachbin André, IMPA, Rio de Janeiro; 09.02.2018 - 17.02.2018, AHM

Nachtergaele Bruno, UC Davis; 13.05.2018 - 25.05.2018, MSC

Nadareishvili George, Tbilisi State U; 17.11.2018 - 24.11.2018, CSR

Nägerl Hanns-Christoph, U Innsbruck; 11.04.2018 - 13.04.2018, MSC

Nahum Adam, U of Oxford; 08.04.2018 - 14.04.2018, MSC

Nair Parameswaran , CUNY; 08.07.2018 - 15.07.2018, OST

Nannen Lothar, TU Vienna; 16.07.2018 - 20.07.2018, PSH

Nawratil Georg, TU Vienna; 24.09.2018 - 28.09.2018, GNB

Nazaroglu Caner, U Cologne; 09.09.2018 - 14.09.2018, WTW

Negri Matteo, U of Pavia; 19.08.2018 - 24.08.2018, DFS

Neilan Michael, U of Pittsburgh; 15.07.2018 - 21.07.2018, PSH

Nest Ryszard, U of Copenhagen; 04.11.2018 - 30.11.2018, CSR

Ngô Bao Châu, U of Chicago; 16.03.2018 - 19.03.2018, IS

Nguyen Tung, U of Wisconsin, Madison; 14.10.2018 - 20.10.2018, CMF

Niemimäki Ossi, U Helsinki; 17.11.2018 - 24.11.2018, CSR

Nieri Fabrizio, Uppsala U; 02.09.2018 - 08.09.2018, BTZ

Nishimura Jun, KEK Theory Center, Tsukuba; 07.07.2018 - 14.07.2018, OST

Nivoche Stéphanie, U Nice Sophia Antipolis, Nice; 11.12.2018 - 16.12.2018, GLO

Nixon Anthony, Lancaster U; 23.09.2018 - 30.09.2018, GNB

Nobile Fabio, EPFL, Lausanne; 09.07.2018 - 13.07.2018, PSH

Nochetto Ricardo, U of Maryland; 15.07.2018 - 27.07.2018, PSH

Nouy Anthony, Ecole Centrale Nantes; 02.06.2018 - 15.06.2018, PSH

Oberthaler Markus, Kirchhoff Institute for Physics, Heidelberg; 08.04.2018 - 13.04.2018, MSC; 21.05.2018 - 24.05.2018, MSC

O'Connor Denjoe, Dublin Institute for Advanced Studies; 07.07.2018 - 13.07.2018, OST

Ohlberger Mario, U of Münster; 25.06.2018 - 29.06.2018, PSH

Ohsawa Takeo, Nagoya U; 08.12.2018 - 15.12.2018, GLO

Okamoto Hisashi, Gakushuin U, Tokyo; 22.02.2018 - 03.03.2018, AHM

Olasloaga Maria Josefina, U of Miami; 12.03.2018 - 18.03.2018, AHM

Oliynyk Todd, Monash U, Clayton; 31.07.2018 - 05.08.2018, IS

Orlando Gianluca, TU Munich; 19.08.2018 - 24.08.2018, DFS

Ornaghi Mattia, U di Milano; 15.10.2018 - 15.02.2019, JRF

Ortega Castillo Sofia, CIMAT, Guanajuato; 09.12.2018 - 15.12.2018, GLO

Ortega-Cerda Joaquim, U Barcelona; 18.03.2018 - 23.03.2018, CGP
Oshikawa Masaki, U of Tokyo; 30.04.2018 - 06.05.2018, MSC; 12.05.2018 - 16.05.2018, MSC; 28.05.2018 - 02.06.2018, MSC
Owen John, U Cambridge; 26.09.2018 - 29.09.2018, GNB
Oyarzun Diego, Imperial College London; 14.10.2018 - 17.10.2018, CMF
Pagliari Valerio, U of Pisa; 19.08.2018 - 24.08.2018, DFS
Pal Arijeet, Oxford U; 12.05.2018 - 18.05.2018, MSC
Paldor Nathan, The Hewbrew U of Jerusalem; 01.03.2018 - 10.03.2018, AHM
Pan Albert, D.E. Shaw Research, New York; 30.09.2018 - 04.10.2018, DKB
Panina Gaiane, Steklov Institute, St. Petersburg; 21.09.2018 - 29.09.2018, GNB
Pantea Casian, West Virginia U, Morgantown; 14.10.2018 - 20.10.2018, CMF
Paredes Maria Belen, LMU Munich; 16.05.2018 - 18.05.2018, MSC
Park Jihun, IBS/Postech, Pohang; 01.08.2018 - 31.08.2018, RIT
Pawlaschyk Thomas, Bergische U Wuppertal; 08.12.2018 - 14.12.2018, GLO
Pereverzyev Sergei, RICAM, Linz; 25.06.2018 - 29.06.2018, PSH
Perez de Alba Ortiz Alberto, U of Amsterdam; 29.09.2018 - 03.10.2018, DKB
Perfekt Karl-Mikael, U of Reading; 18.03.2018 - 23.03.2018, CGP
Perugia Ilaria, U Vienna, 11.06.2018 - 17.08.2018, PSH
Peter Christine, U of Konstanz; 01.10.2018 - 02.10.2018, DKB
Peters Baron, UC Santa Barbara; 30.09.2018 - 04.10.2018, DKB
Peterseim Daniel, U Augsburg; 23.06.2018 - 09.07.2018, PSH; 11.07.2018 - 22.07.2018, PSH
Petersen Philipp, TU Berlin; 11.06.2018 - 15.06.2018, PSH
Piazzalunga Nicolo, Suny Stony Brook, New York; 05.09.2018 - 10.09.2018, BTZ
Pichler Alexander, U Vienna; 25.06.2018 - 29.06.2018, PSH; 16.07.2018 - 20.07.2018, PSH
Pietrucci Fabio, Sorbonne U, Paris; 30.09.2018 - 03.10.2018, DKB
Pioline Boris, LPTHE, U Pierre et Marie Curie, Paris; 10.09.2018 - 14.09.2018, WTW
Piovano Paolo, U Vienna; 20.08.2018 - 24.08.2018, DFS
Piroli Lorenzo, SISSA & INFN, Trieste; 15.04.2018 - 27.04.2018, MSC
Poilblanc Didier, U Toulouse III; 14.05.2018 - 18.05.2018, MSC
Polettini Matteo, U Luxembourg; 15.10.2018 - 19.10.2018, CMF
Polkovnikov Anatoli, Boston U; 14.05.2018 - 18.05.2018, MSC
Pollmann Frank, TU Munich; 16.05.2018 - 18.05.2018, MSC
Ponsiglione Marcello, U of Rome "La Sapienza"; 19.08.2018 - 26.08.2018, DFS
Portisch Stefan, TU Vienna ; 15.10.2018 - 16.10.2018, CMF
Power Stephen, Lancaster U; 19.09.2018 - 29.09.2018, GNB
Prabhu Rahul, U of Florida, Gainesville; 23.09.2018 - 29.09.2018, GNB
Pradovera Davide, EPFL, Lausanne; 09.07.2018 - 13.07.2018, PSH
Praetorius Dirk, TU Vienna; 16.07.2018 - 20.07.2018, PSH
Prešnajder Peter, U Comenius, Bratislava; 09.07.2018 - 13.07.2018, OST
Prodan Emil, Yeshiva U, New York; 18.11.2018 - 24.11.2018, CSR
Proietti Valerio, MPI Bonn; 25.11.2018 - 01.12.2018, CSR
Prosen Tomaź, U of Ljubljana; 21.05.2018 - 31.05.2018, MSC
Protasov Vladimir, Moscow State U; 20.03.2018 - 25.03.2018, CGP
Putinar Mihai, UC, Santa Barbara; 17.03.2018 - 25.03.2018, CGP
Puttkammer Sophie Louise, Humboldt U zu Berlin; 06.08.2018 - 10.08.2018, PSH
Qin Lin, TU Vienna; 01.10.2018 - 03.10.2018, DKB
Quirchmayr Ronald, KTH, Royal Institute of Technology; 12.02.2018 - 23.02.2018, AHM
Rakhuba Maksim, ETH Zurich; 10.06.2018 - 16.06.2018, PSH
Ramgoolam Sanjaye, Queen Mary U of London; 08.07.2018 - 8.07.2018, OST

Rao Peng, IST Austria; 09.04.2018 - 13.04.2018, MSC

Rapcan Peter, Slovak Academy of Sciences, Bratislava; 29.10.2018 - 30.10.2018, IS

Rasamat Shlomo-Sergei, Technion, Haifa; 02.09.2018 - 09.09.2018, BTZ

Rasoulzadeh Arvin, TU Vienna; 27.09.2018 - 28.09.2018, GNB

Rätzel Dennis, U Vienna; 09.04.2018 - 12.04.2018, MSC

Rauhut Holger, RWTH Aachen & U Aachen; 09.06.2018 - 14.06.2018, PSH

Rayhaun Brandon, Stanford U; 09.09.2018 - 15.09.2018, WTW

Regensburger Georg, JKU Linz; 15.10.2018 - 19.10.2018, CMF

Reich Sebastian, U Potsdam; 24.06.2018 - 29.06.2018, PSH

Reitzner Daniel, Slovak Academy of Sciences, Bratislava; 29.10.2018 - 30.10.2018, IS

Rendall Alan, Johannes Gutenberg U, Mainz; 15.10.2018 - 20.10.2018, CMF

Rennie Adam, U of Wollongong; 03.11.2018 - 03.12.2018, CSR

Reys Valentin, U Milano-Biccoca; 09.09.2018 - 15.09.2018, WTW

Rieder Alexander, U Vienna; 11.06.2018 - 15.06. 20187, PSH

Riedler Wolfgang, U of Alberta, Edmonton; 09.09.2018 - 18.09.2018, WTW

Rigol Marcos, Penn State U; 07.05.2018 - 13.05.2018, MSC

Robinson Neil, U of Amsterdam; 27.05.2018 - 03.06.2018, MSC

Rodríguez Sanjurjo Adrian, U College Cork; 25.02.2018 - 04.03.2018, AHM

Rogal Jutta, Ruhr U Bochum; 30.09.2018 - 04.10.2018, DKB

Romanovskij Valerij, U of Maribor; 14.10.2018 - 18.10.2018, CMF

Romero José Luis, U Vienna; 19.03.2018 - 23.03.2018, CGP

Rossi Riccarda, U degli studi di Brescia; 19.08.2018 - 23.08.2018, DFS

Roubícek Tomás, Charles U, Prague; 19.08.2018 - 25.08.2018, DFS

Rozza Gianluigi, SISSA, Trieste; 25.06.2018 - 28.06.2018, PSH

Rubin Alessandro, SISSA, Trieste; 18.11.2018 - 01.12.2018, CSR

Ruffo Stefano, SISSA, Trieste; 16.06.2018 - 18.06.2018, SAB

Ruggeri Michele, U Vienna; 16.07.2018 - 20.07.2018, PSH; 20.08.2018 - 24.08.2018, DFS

Ruppenthal Jean, U Wuppertal; 10.12.2018 - 14.12.2018, GLO

Sabino Jaão, TU Vienna; 09.04.2018 - 08.06.2018, MSC

Sadeghi Manesh Amirhossein, U of Copenhagen; 14.10.2018 - 19.10.2018, CMF

Sahutoglu Sonmez, U of Toledo; 08.12.2018 - 15.12.2018, GLO

Sakharwade Nitica, Perimeter Institute, Waterloo; 17.09.2018 - 28.09.2018, IS

Sako Akifumi, Tokyo U of Science; 11.07.2018 - 14.07.2018, OST

Samelson Roger, Oregon State U; 08.03.2018 - 14.03.2018, AHM

Sangalli Giancarlo, U di Pavia; 14.07.2018 - 20.07.2018, PSH

Sapsis Themistoklis, MIT, Massachusetts; 11.03.2018 - 16.03.2018, AHM

Sauer Tomas, U Passau; 18.03.2018 - 23.03.2018, CGP

Sauter Stefan, U Zurich; 24.06.2018 - 29.06.2018, PSH

Sayas Francisco J., U of Delaware; 25.06.2018 - 29.06.2018, PSH

Scala Riccardo, U of Lisbon; 19.08.2018 - 25.08.2018, DFS

Schack Ruediger, U of London; 28.10.2018 - 30.10.2018, IS

Scharler Daniel, U Innsbruck; 23.09.2018 - 28.09.2018, GNB

Scheiderer Claus, U Konstanz; 18.03.2018 - 24.03.2018, CGP

Scheithauer Nils, TU Darmstadt; 09.09.2018 - 16.09.2018, WTW

Scherzer Otmar, U Vienna; 25.06.2018 - 30.06.2018, PSH

Schicho Josef, JKU Linz; 24.09.2018 - 28.09.2018, GNB

Schillings Claudia, U of Mannheim; 11.06.2018 - 29.06.2018, PSH

Schimpf Maria, TU Vienna; 10.09.2018 - 14.09.2018, WTW

Schlenker Jean-Marc, U Luxembourg; 25.09.2018 - 27.09.2018, GNB

Schlömerkemper Anja, U of Würzburg; 19.08.2018 - 24.08.2018, DFS

Schmalz Gerd, U of New England, Armidale; 09.12.2018 - 14.12.2018, GLO

Schmidt Bernd, AEI, Golm; 02.08.2018 - 05.08.2018, IS

Schmiedmayer Jörg, TU Vienna; 06.04.2018 - 08.06.2018, MSC

Schmüdgen Konrad, U Leipzig; 18.03.2018 - 23.03.2018, CGP

Schneider Reinhold, TU Berlin; 11.06.2018 - 15.06.2018, PSH; 25.06.2018 - 28.06.2018, PSH

Schneider Ulrich, U of Cambridge; 10.04.2018 - 13.04.2018, MSC

Schöberl Joachim, TU Vienna; 25.06.2018 - 29.06.2018, PSH

Schoutens Kareljan, U of Amsterdam; 30.04.2018 - 03.05.2018, MSC; 23.05.2018 - 01.06.2018, MSC

Schröder Andreas, U of Salzburg; 15.07.2018 - 20.07.2018, PSH

Schröcker Hans-Peter, U Innsbruck; 23.09.2018 - 27.09.2018, GNB

Schuricht Dirk, Utrecht U; 16.04.2018 - 19.04.2018, MSC; 07.05.2018 - 09.05.2018, MSC

Schulz-Baldes Hermann, U Erlangen-Nürnberg; 31.10.2018 - 15.11.2018, CSR

Schulze Bernd, Lancaster U; 23.09.2018 - 30.09.2018, GNB

Schuster Peter, U Vienna; 15.10.2018 - 19.10.2018, CMF; 29.10.2018 - 30.10.2018, IS

Schwab Christoph, ETH Zurich; 10.06.2018 - 27.06.2018, PSH; 15.07.2018 - 22.07.2018, PSH; 02.08.2018 - 11.08.2018, PSH

Sciarappa Antonio, KIAS, Seoul; 02.09.2018 - 08.09.2018, BTZ

Seifert Udo, U Stuttgart; 28.10.2018 - 30.10.2018, IS

Seiringer Robert, IST Austria; 11.04.2018 - 13.04.2018, MSC

Sera Martin, Chalmers U; 09.12.2018 - 15.12.2018, GLO

Serbyn Maksym, IST Austria; 09.04.2018 - 13.04.2018, MSC; 21.05.2018 - 08.06.2018, MSC

Serra Mattia, Harvard U; 09.03.2018 - 16.03.2018, AHM

Servatius Brigitte , Worcester Polytechnic Institute; 23.09.2018 - 29.09.2018, GNB

Servatius Herman, Worcester Polytechnic Institute; 23.09.2018 - 29.09.2018, GNB

Shabbir Huzaifa, U Vienna; 01.10.2018 - 03.10.2018, DKB

Shafikov Rasul, U of Western Ontario; 09.12.2018 - 15.12.2018, GLO

Shakir Qays, National U Ireland, Gaiway; 23.09.2018 - 28.09.2018, GNB

Shantanu Dave, U Vienna ; 26.11.2018 - 30.11.2018, CSR

Shcherbina Nikolay, U Wuppertal; 09.12.2018 - 15.12.2018, GLO

Shcherbakov Viktor, Lavrentyev Institute of Hydrodynamics, Novosibirsk & Novosibirsk State U; 19.08.2018 - 24.08.2018, DFS

Shi Zuoqiang, Tsinghua U; 24.06.2018 - 03.07.2018, PSH

Shivani Krishnamurthy Vikas, Federal U of Pernambuco, Recife; 31.03.2018 - 01.08.2018, JRF

Shramov Konstantin, Steklov Mathematical Institute, Moscow & Higher School of Economics, Moscow, Russia; 01.08.2018 - 15.08.2018, RiT

Sierra German, U Autonoma Madrid; 13.05.2018 - 19.05.2018, MSC

Sikora Mateusz, MPI Frankfurt/M; 01.10.2018 - 03.10.2018, DKB

Silva Alessandro, SISSA, Trieste; 22.04.2018 - 27.04.2018, MSC

Şimşek Ceyda, U of Groningen; 03.01.2018 - 03.03.2018, SFS

Singraber Andreas, U Vienna; 01.10.2018 - 03.10.2018, DKB

Sitharam Meera, U of Florida ; 23.09.2018 - 29.09.2018, GNB

Shimada Hidehiko, Okinawa Institute for Science and Technology; 08.07.2018 - 14.07.2018, OST

Skarke Harald, TU Vienna; 10.09.2018 - 14.09.2018, WTW

Smak Pavel, Masaryk U, Brno; 30.09.2018 - 03.10.2018, DKB

Smears Iain, University College London; 15.07.2018 - 22.07.2018, PSH

Solombrino Francesco, U degli Studi "Federico 2", Napoli; 19.08.2018 - 24.08.2018, DFS

Song Bailin, U of Science and Technology Hefei; 09.09.2018 - 15.09.2018, WTW

Souvaine Diane, Tufts U, Medford; 23.09.2018 - 29.09.2018, GNB

Sperling Marcus, U Vienna; 09.07.2018 - 12.07.2018, OST
Stachel Hellmuth, TU Vienna; 24.09.2018 - 28.09.2018, GNB
Stamm Benjamin, RWTH Aachen U; 24.06.2018 - 29.06.2018, PSH
Stamper-Kurn Dan, U of California, Berkeley; 09.04.2018 - 14.04.2018, MSC
Stehouwer Luuk, U Amsterdam; 25.11.2018 - 03.12.2018, CSR
Steinacker Harold, U Vienna; 09.07.2018 - 13.07.2018, OST; 28.11.2018 - 29.11.2018, CSR
Steinbach Olaf, TU Graz; 16.07.2018 - 19.07.2018, PSH
Steinert-Berndt Silke, U Bonn; 13.08.2018 - 24.08.2018, IS
Stern Allen, U of Alabama, Tuscaloosa; 07.07.2018 - 15.07.2018, OST
Stevenson Rob, U of Amsterdam; 15.07.2018 - 19.07.2018, PSH
Stimming Hans Peter, U Vienna; 09.04.2018 - 13.04.2018, MSC
Stocker Paul, U Vienna; 01.06.2018 - 20.07.2018, PSH; 25.06.2018 - 29.06.2018, PSH
Stöckler Joachim, TU Dortmund; 18.03.2018 - 23.03.2018, CGP
Stoiber Tom, FAU Erlangen-Nürnberg; 18.11.2018 - 23.11.2018, CSR
Stolovitch Laurent, CNRS, U de Nice Sophia Antipolis; 08.12.2018 - 11.12.2018, GLO
Stoppa Jacopo, SISSA, Trieste; 26.08.2018 - 08.09.2018, BTZ
Straube Emil J., Texas A&M U, College Station; 09.12.2018 - 15.12.2018, GLO
Stringari Sandro, U Trento; 10.04.2018 - 18.04.2018, MSC
Sung Li-Yeng, Louisiana State U; 23.06.2018 - 01.07.2018, PSH
Strohmer Thomas, UC Davis; 18.03.2018 - 23.03.2018, CGP; 10.06.2018 - 16.06.2018, PSH
Sung Li-Yeng, Louisiana State U; 23.06.2018 - 01.07.2018, PSH
Stroppel Catharina, U Bonn; 16.06.2018 - 18.06.2018, SAB
Stuart Andrew, Caltech, Pasadena ; 24.06.2018 - 29.06.2018, PSH
Sugino Fumihiko, Institute for Basic Science (IBS), Yuseong-Gu; 08.07.2018 - 14.07.2018, OST
Sun Qiyu, U of Central Florida; 18.03.2018 - 21.03.2018, CGP
Swenson David, U of Amsterdam; 30.09.2018 - 04.10.2018, DKB
Sykora Andreas, U Munich; 10.07.2018 - 14.07.2018, OST
Szederkényi Gábor, Pázmány Péter Catholic U, Budapest ; 14.10.2018 - 19.10.2018, CMF
Szmolyan Peter, TU Vienna; 15.10.2018 - 19.10.2018, CMF
Tagliacozzo Luca, U of Strathclyde; 20.05.2018 - 26.05.2018, MSC
Tajik Mohammadamin, TU Vienna; 09.04.2018 - 08.06.2018, MSC
Takacs Gabor, Budapest U of Technology and Economics; 27.05.2018 - 06.06.2018, MSC
Takacs Thomas, JKU Linz; 16.07.2018 - 20.07.2018, PSH
Tanzini Alessandro, SISSA, Trieste; 24.08.2018 - 06.09.2018, BTZ
Taormina Anne, Durham U; 09.09.2018 - 15.09.2018, WTW
Tartaglia Elena, Sissa, Trieste; 29.05.2018 - 06.06.2018, MSC
Tekel Juraj, Comenius U, Bratislava; 09.07.2018 - 13.07.2018, OST
Tél Tamás, Eötvös U; 11.03.2018 - 17.03.2018, AHM
Theran Louis, U St. Andrews, Scotland; 24.09.2018 - 27.09.2018, GNB
Thiang Guo Chuan, U Adelaide; 21.11.2018 - 30.11.2018, CSR
Thomas Gareth, U College Cork; 15.02.2018 - 21.02.2018, AHM; 11.03.2018 - 17.03.2018, AHM
Thomas Richard, Imperial College London; 03.09.2018 - 07.09.2018, BTZ
Tiwary Pratyush, U of Maryland, College Park; 30.09.2018 - 04.10.2018, DKB
Toda Yukinobu, U of Tokyo; 02.09.2018 - 07.09.2018, BTZ
Tonello Elisa, FU Berlin; 14.10.2018 - 19.10.2018, CMF
Tóth János, Budapest U Technology and Economics; 14.10.2018 - 20.10.2018, CMF
Trnka Tomas, SCM, Amsterdam ; 01.10.2018 - 03.10.2018, DKB
Trombettoni Andrea, CNR-IOM & SISSA, Trieste; 19.04.2018 - 05.04.2018, MSC
Tröster Andreas, U Vienna; 01.10.2018 - 03.10.2018, DKB

Trussardi Lara, U Vienna; 22.08.2018 - 25.08.2018, DFS
Tsuchiya Asato, Shizuoka U; 07.07.2018 - 14.07.2018, OST
Tsvelik Alexei, Brookhaven National Laboratory; 30.04.2018 - 11.05.2018, MSC
Tuybens Benoit, U Gent; 27.05.2018 - 02.06.2018, MSC
Uffink Jos, U of Minnesota, Minneapolis; 27.10.2018 - 01.11.2018, IS
Usachev Alexnadr, U of Gothenburg, Chalmers; 18.1.2018 - 02.12.2018, CSR
Vallis Geoffrey, U Exeter; 30.01.2018 - 02.02.2018, AHM
van Damme Maarten, U of Gent; 27.05.2018 - 02.06.2018, MSC
Van den Dungen Koen, U Bonn; 21.11.2018 - 01.12.2018, CSR
Vanden-Eijnden Eric, New York U; 11.03.2018 - 15.03.2018, AHM
Vanderstraeten Laurens, U of Gent; 29.05.2018 - 01.06.2018, MSC
Van Erp Titus, NTNU Trondheim; 30.09.2018 - 04.10.2018, DKB
Van Goethem Nicolas, U of Lisbon; 19.08.2018 - 24.08.2018, DFS
Vanhecke Bram, U of Gent; 27.05.2018 - 02.06.2018, MSC
van Nieuwkerk Yuri Daniel, U of Oxford; 14.04.2018 - 21.04.2018, MSC; 28.05.2018 - 02.06.2018, MSC
Van Nuland Teun, Radboud U Nymegen; 18.11.2018 - 24.11.2018, CSR
Van Schuppen Jan H., Delft U of Technology; 14.10.2018 - 17.10.2018, CMF
Van Velthoven Jordy Timo, U Vienna; 19.11.2018 - 23.11.2018, CSR
Vassena Nicola, FU Berlin ; 14.10.2018 - 19.10.2018, CMF
Vasy Andras, Stanford U; 27.08.2018 - 31.08.2018, CBS; 27.06.2018 - 01.07.2018, IS
Vázquez Hermández Rafael, EPFL, Lausanne; 15.07.2018 - 20.07.2018, PSH
Velčić Igor, U of Zagreb; 19.08.2018 - 25.08.2018, DFS
Venkatesh Vilasini, U of York; 15.09.2018 - 21.09.2018, IS
Verbeke Bert, KU Leuven; 26.05.2018 - 01.07.2018, JRF
Verfürth Barbara, U Münster; 24.06.2018 - 07.07.2018, PSH
Verhellen Jonas, U Gent; 27.05.2018 - 02.06.2018, MSC
Vernier Eric, U of Oxford; 28.05.2018 - 02.06.2018, MSC
Verstraete Frank, U Vienna; 09.04.2018 - 30.04.2018, MSC
Villari Gabriele, U of Florence; 11.03.2018 - 18.03.2018, AHM
Vilmart Gilles, U of Geneva; 24.06.2018 - 05.07.2018, PSH
Vincze Miklos, MTE-ELTE Theoretical Physics Research Group, Budapest; 11.03.2018 - 17.03.2018, AHM
Viscardi Alberto, U dlegi studio di Milano, Bicocca; 18.03.2018 - 23.03.2018, CPG
Voigt Christian, U Glasgow; 21.11.2018 - 24.11.2018, CSR
Volpato Roberto, U Padova; 09.09.2018 - 14.09.2018, WTW
Wadhawan Arjun, U Amsterdam; 01.10.2018 - 03.10.2018, DKB
Walcher Sebastian, RWTH Aachen; 14.10.2018 - 20.10.2018, CMF
Wolfram Marie-Therese, RICAM Austria & U Warwick; 25.06.2018 - 25.06.2018, PSH
Waschbichler Florian, U Passau; 18.03.2018 - 25.03.2018, CGP
Watamura Satoshi, Tohoku U, Seidan; 07.07.2018 - 15.07.2018, OST
Weare Jonathan, U Chicago; 25.06.2018 - 29.06.2018, PSH
Weber Andreas, U Bonn; 16.10.2018 - 18.10.2018, CMF
Weber Jan Erik H., U of Oslo; 04.03.2018 - 09.03.2018, MSC
Weiss David, Penn State U; 07.05.2018 - 13.05.2018, MSC
Wendland Katrin, Albert Ludwigs U Freiburg; 09.09.2018 - 15.09.2018, WTW
Wenmackers Sylvia, KU Leuven; 28.10.2018 - 30.10.2018, IS
Werndl Charlotte, U of Salzburg; 29.10.2018 - 30.10.2018, IS
Wheeler Miles H., U of Vienna; 22.01.2018 - 23.03.2018, AHM

Wilkens Jadwiga, FU Berlin ; 16.09.2018 - 22.09.2018, IS
Will Sebastian, Columbia U; 15.04.2018 - 21.04.2018, MSC
Williams Jarrod, Queen Mary U of London; 02.11.2018 - 28.02.2019, JRF
Wiuf Carsten, U of Copenhagen; 14.10.2018 - 19.10.2018, CMF
Wrase Timm, TU Wien; 10.09.2018 - 14.09.2018, WTW
Wu Ru Gway, TU Vienna ; 09.04.2018 - 13.04.2018, MSC
Wulkenhaar Raimar, U Münster; 04.11.2018 - 08.11.2018, CSR
Wutte Raphaela, TU Vienna; 10.09.2018 - 14.09.2018, WTW
Xu Chuang, U of Copenhagen; 14.10.2018 - 20.10.2018, CMF
Yamamori Atsushi, Kogakuin U; 09.12.2018 - 15.12.2018, GLO
Yamazaki Masahito, Kavli IPM, U Tokyo; 31.08.2018 - 07.09.2018, BTZ
Yokura Shoji, U of Kagoshima; 19.11.2018 - 29.11.2018, CSR
Yu Polly, U of Wisconsin-Madison; 13.10.2018 - 20.10.2018, CMF
Yuncken Robert, U Clermont Auvergne; 13.10.2018 - 23.10.2018, CSR
Zabell Sandy, Northwestern U, Evanston; 27.10.2018 - 01.11.2018, IS
Zabzine Maxim, U Uppsala; 26.08.2018 - 07.09.2018, BTZ
Zagier Don, MPI, Bonn; 09.09.2018 - 14.09.2018, WTW
Zank Marco, TU Graz; 16.07.2018 - 20.07.2018, PSH
Zhangellini Jürgen, BOKU Vienna; 15.10.2018 - 19.10.2018, CMF
Zarand Gergely, Budapest U of Technology and Economics; 07.05.2018 - 09.05.2018, MSC
Zech Jakob, ETH Zurich; 10.06.2018 - 29.06.2018, PSH
Zeidler Rudolf, U Münster; 17.11.2018 - 24.11.2018, CSR
Zeiher Johannes, MPI, Garching; 23.04.2018 - 27.04.2018, MSC
Zeppieri Caterina Ida, WWU Münster; 19.08.2018 - 24.08.2018, DFS
Zeytuncu Yunus, U of Michigan, Dearborn; 10.12.2018 - 13.12.2018, GLO
Zheludev Andrey, ETH Zurich; 30.04.2018 - 05.05.2018, MSC
Zhu Weixia, Rutgers U Camden; 09.12.2018 - 15.12.2018, GLO
Zimet Maxwell, Stanford U; 08.09.2018 - 15.09.2018, WTW
Zimmer Marcel, U of Cologne; 18.11.2018 - 30.11.2018, CSR
Ziolkowska Aleksandra, U of Oxford; 13.04.2018 - 22.04.2018, MSC
Zoettl Andreas, ESPCI, Paris; 01.09.2018 - 31.12.2018, JRF
Zoupanos George, National Technical U (NTUA), Athens; 08.07.2018 - 11.07.2018, OST
Žubrinić Josip, U of Zagreb; 19.08.2018 - 24.08.2018, DFS
Zwegers Sander, U Cologne; 09.09.2018 - 14.09.2018, WTW
Zwicknagl Barbara, TU Berlin; 20.08.2018 - 24.08.2018, DFS
Zwikel Celine, U Libre de Bruxelles; 10.09.2018 - 14.09.2018, WTW

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