Institut Mittag-Leffler is an international center for research and postdoctoral training in the mathematical sciences. It was founded in 1916 by professor Gösta Mittag-Leffler and is the oldest mathematics research institute in the world. It operates under the auspices of the Royal Swedish Academy of Sciences and is governed by a board with representatives from all Nordic countries.

The premises of the institute encompass several buildings: the main building including a library, office and discussion spaces for researchers and staff, a seminar room building, and five other buildings with housing facilities for visiting researchers. The mission of Institut Mittag-Leffler is to support international top-level research in mathematics, with special attention to the development in the Nordic countries. The institute is a hub for the international mathematical research community and for mathematicians in the Nordic countries.

The main activities include research programs, conferences, workshops, seminars and summer schools, which all aim to conduct and develop current mathematical research. Research programs and conferences have organizing committees approved by the board. Based on the recommendations of the organizing committees, mathematicians are invited to stay and work at the institute. Junior program participants are offered fellowships to finance their stays. Although mathematicians from the Nordic countries are given some priority, the institute works actively to ensure diversity among program participants.

The institute also publishes two mathematical journals, Acta Mathematica (founded by Gösta Mittag-Leffler in 1882) and Arkiv för matematik (founded in 1903). Acta is one of a small number of exclusive world-leading international mathematics research journals and one of the highest rated journals in the mathematical world. All volumes of both journals are freely available online.
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A BRIEF REVIEW OF 2018

On September 1, I started as director of Institut Mittag-Leffler, replacing Ari Laptev after seven successful years. At the same time, Hans Ringström replaced me as deputy director. It is a humbling task to lead the institute with its long and successful history.

The institute will continue in the spirit of the last years seeking to attract world leading mathematicians to programs and conferences. We will also continue the dialogue with Nordic mathematics departments, other international mathematics research institutes, the Swedish Research Council, The Wallenberg Foundations, the Research Council of Norway, and the Verg Foundation. Also, the editorial work with Acta Mathematica and Arkiv för matematik, and the cooperation with International Press, continue.

During 2018, the institute organized two longer research programs:

- **Tropical Geometry, Amoebas and Polytopes**
- **Mathematical Biology**

The programs included three conferences sponsored by the Simons Foundation:

- Workshop on **Tropical Varieties and Amoebas in Higher Dimension**, April 16–20
- Workshop 1010: **The Maths of Biology**, October 8–12
- **Days on Multiscale Modelling in Tissue and Cancer Growth**, December 10–11

The institute also hosted ten week-long research conferences:

- **Interfaces between Geometric Analysis and Mathematical Physics**
- **Eigenvalues and Inequalities**
- **Nonlocal Interactions in Partial Differential Equations and Geometry**
- **Hausdorff Geometry of Polynomials and Polynomial Sequences**
- **Analysis of operators on Function Spaces: A Conference Dedicated to the Mathematics of Serguei Shimorin**
- **Workshop on Nonlinear Parabolic PDEs**
- **Gaussian Fields in Random Matrix Theory**
- **N-Cube Week**
- **Algebraic and Geometric Aspects of Numerical Methods for Differential Equations**
- **Categorification and Higher Representation Theory**

Apart from these regular research activities, there were the following additional events:

On October 17–18, the institute hosted the **Rolf Schock Prize Symposia in Mathematics**, with laureate Ronald Coifman, and in **Logics**.
Together with the National Centre for Mathematics Education (NCM), the institute organized the Klein Days, a teaching workshop for high-school teachers in mathematics: in January, June and August. These events were funded entirely by generous support from Brummer & Partners. At the June meeting, the Swedish minister of high-school education, Anna Ekström, visited the Klein Days.

The institute was involved in different Nordic and international collaborations. In May, the institute organized the annual meeting of chairmen of the major Mathematics Departments in all Nordic countries. In April, it chaired the yearly meeting of ERCOM, a committee of the European Mathematical Society including around 30 European research institutes in mathematics.

During 2018, the institute expanded its administrative team. In April, Sofie Holm started as head of administration and, in October, Sara Dalström as financial assistant and administrative coordinator. We have also established a closer cooperation with the property owner, the Royal Swedish Academy of Sciences, regarding the facilities of the institute, working with the facility manager Jonas Lif.

Institut Mittag-Leffler is very grateful to all those who contributed during 2018. First and foremost, to all mathematicians who chose to conduct their research at the institute and to contribute to its scientific environment, especially to our colleagues in Sweden and other Nordic countries. We also thank all organizations that have contributed to us financially: Brummer & Partners, Chalmers/Gothenburg University, Linköping University, Luleå University of Technology, Lund University, the Acta Mathematica Foundation, the Anna-Greta and Holger Crafoord Foundation, the Danish Mathematical Society, the Academy of Finland, the G S Magnuson Foundation, the Icelandic Centre for Research, the Knut and Alice Wallenberg Foundation, the Research Council of Norway, the KTH Royal Institute of Technology, the Simons Foundation, Stockholm University, the Swedish Research Council, the Verg Foundation, Uppsala University, Umeå University.

Finally, the staff of the institute and their colleagues at the Royal Swedish Academy of Sciences have done an admirable job to ensure that both the institute itself and all its activities run smoothly and effectively.

Tobias Ekholm
Director
THE BOARD OF INSTITUT MITTAG-LEFFLER
The board of Institut Mittag-Leffler consists of representatives of the Nordic countries and members appointed by the class of mathematics of the Royal Swedish Academy of Sciences.

MEMBERS OF THE BOARD, MAY 4, 2018:
MICHAEL BENEDICKS, Uppsala University, Stockholm, Sweden
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RAGNAR SIGURDSSON, University of Iceland
ANNA-KARIN TORNBERG, KTH Royal Institute of Technology, Stockholm, Sweden
PUBLICATIONS

Acta Mathematica
2 volumes per year (4 issues, 800 pages)
During 2018 the issues 220:1, 220:2, 221:1 and 221:2 were published with in total 12 articles.

EDITORIAL COMMITTEE
Editor-in-Chief:
Tobias Ekholm (Institut Mittag-Leffler and Uppsala University)
Technical Editor:
Federico Incitti
Editors:
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Tobias Holck Colding (Massachusetts Institute of Technology, Cambridge)
Jesper Grodal (University of Copenhagen)
Helge Holden (NTNU – Norwegian University of Science and Technology, Trondheim)
Kurt Johansson (KTH Royal Institute of Technology, Stockholm)
Eero Saksman (University of Helsinki)

Arkiv för matematik
1 volume per year (2 issues, 400 pages)
The issues 56:1 and 56:2 were published during 2018 with in total 25 articles.

EDITORIAL COMMITTEE
Editor-in-Chief:
Hans Ringström (Institut Mittag-Leffler and KTH Royal Institute of Technology, Stockholm)
Editorial Assistant:
Maria Weiss, Institut Mittag-Leffler
Editors:
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Carel Faber (Utrecht University)
Pär Kurlberg (KTH Royal Institute of Technology, Stockholm)
Volodymyr Mazorchuk (Uppsala University)
Erik Wahlén (Lund University)

SUPPORTING ORGANIZATIONS
THE ACADEMY OF FINLAND
THE ACTA MATHEMATICA FOUNDATION
THE ANNA-GRETA AND HOLGER CRAFOORD FOUNDATION
BRUMMER & PARTNERS
THE DANISH MATHEMATICAL SOCIETY
THE G S MAGNUSON FOUNDATION
GOTHENBURG UNIVERSITY/CHALMERS UNIVERSITY OF TECHNOLOGY
THE ICELANDIC CENTRE FOR RESEARCH
THE KNUT AND ALICE WALLENBERG FOUNDATION
THE KTH ROYAL INSTITUTE OF TECHNOLOGY
LINKÖPING UNIVERSITY
LULEÅ UNIVERSITY OF TECHNOLOGY
LUND UNIVERSITY
THE RESEARCH COUNCIL OF NORWAY
THE SIMONS FOUNDATION
STOCKHOLM UNIVERSITY
THE SWEDISH RESEARCH COUNCIL
UMEÅ UNIVERSITY
UPPSALA UNIVERSITY
THE VERG FOUNDATION
SCIENTIFIC REPORT

SCIENTIFIC BACKGROUND AND PROGRAM

Tropical geometry is a fast growing field at the interface between algebraic geometry and combinatorics with deep connections to many branches of pure mathematics, applied mathematics, and physics. Algebraic varieties can be logarithmically degenerated to tropical varieties, which are polyhedral complexes satisfying certain combinatorial properties. At any intermediate stage before reaching its final limit, the degeneration process yields a structure known as an amoeba. Both tropical varieties and amoebas are dual to subdivisions of polytopes, and this leads to an infusion of combinatorial methods into algebraic, complex-analytic, and non-Archimedean geometry.

The program aimed to strengthen the algebraic, geometric, and combinatorial aspects of tropical geometry, in particular its connections to amoebas and polytopes. It focused on four main areas:

- **Tropical algebra and applications**
- **Combinatorics, polytopes, and complexity**
- **Moduli spaces of curves and mirror symmetry**
- **Tropical geometry and amoebas in higher dimension**

For each area, we held a workshop, in which the main new research directions were presented by the speakers. In non-workshop-weeks, we held biweekly seminars. In addition, we had informal reading and discussion groups on matroids and hyperfields, tropical ideals, tropical surfaces and tropical differential equations.

An interesting outcome of the tropical ideals reading group is the observation that there exist Bergman fans of matroids that are not realizable as the zero locus of any tropical ideal (with multiplicity 1). This shows that tropical ideals are more algebraic in nature than balanced polyhedral complexes. The working groups further raised several fundamental research questions that are currently being studied further.

Some of our participants also gave talks at the KTH Royal Institute of Technology/Stockholm University algebraic geometry seminar. A total of 116 participants visited the institute during the program, among them 23 women. The youngest participants were PhD students. We all enjoyed the inspiring working atmosphere at the institute, with many informal discussions and scientific exchange. A proverbial comment of a participant was to praise the “cold weather and warm atmosphere” of the program.

CONFERENCES

The first three workshops took place at Institut Mittag-Leffler. In addition to the program participants, they attracted visitors from the nearby mathematics departments, KTH Royal Institute of Technology and Stockholm university, but also guests from abroad.
Our final conference was intended to broadly cover the focus topics of the program together with more distantly related areas. It took place at KTH Royal Institute of Technology and was co-organized by Sandra di Rocco. It attracted many additional visitors and was a success, many participants praised the broad spectrum of themes and the inspiring atmosphere.

**Tropical Algebra and Applications**

**January 22–26**

- Felipe Rincon, *Tropical Ideals*
- Ngoc Tran, *Linear and Rational Factorization of Tropical Polynomials*
- Gregorio Malajovich, *Mixed Volume Computations, Tropical Varieties and Quer-massintegralen*
- Jeff Sommars, *Algorithms and Software for Computing Tropical Prevarieties*
- Anders Jensen, *Finding Binomials in Polynomial Ideals*
- Jan Verschelde, *Polyhedral Methods to Solve Polynomial Systems*
- Madeline Brandt, *Computing Berkovich Skeleta of Curves*
- Frederic Bihan, *Criteria for the Strict Monotonicity of Mixed Volumes of Polytopes*
- Emanuele Delucchi, *Some Aspects of Matroids over Hyperfields*
- Kalina Mincheva, *Prime Congruences and Tropical Krull Dimension*
- Boulos El-Hilany, *Constructing Polynomial Systems with Many Positive Solutions Using Tropical Geometry*
- Yoav Len, *Tropical Dual Varieties*
- Xavier Allamigeon, *Log-barrier Interior Point Methods are Not Strongly Polynomial*
- Mark Kambites, *The Multiplicative Structure of Tropical Matrices*
- Yue Ren, *Computing Tropical Varieties Using Newton Polygon Methods*
- Elizabeth Baldwin, *Geometry in Consumer Preferences, Equilibrium and Auction Design*
- Marianne Johnson, *Identities in Upper Triangular Tropical Matrix Semigroups and the Bicyclic Monoid*
- Jan Draisma, *Tropical Aspects of Algebraic Matroids*

We also held a problem session in which questions concerning maximal lattice polygons with prescribed genus, lines in tropical linear spaces, classical versus tropical convex polytopes and generalized permutohedra from tropical linear spaces were discussed.

**Combinatorics, Polytopes, and Complexity**

**February 19–23**

- Raman Sanyal, *A Combinatorial Theory of Valuations on Polytopes*
- Marianne Akian, *Majorization Inequalities for Valuations of Eigenvalues*
- Thorsten Theobald, *Conic Stability of Polynomials*
- Benjamin Schröter, *Rays in the Moduli Space of Tropical Linear Spaces*
- Michael Joswig, *Monomial Tropical Cones for Multicriteria Optimization*
- Jens Forsgård, *Defective Dual Varieties for Real Spectra*
- Bo Lin, *Linear and Rational Factorization of Tropical Polynomials*
- Alicia Dickenstein, *A Bit of Tropical Varieties, a Bit of Polytopes*
- Marvin Hahn, *Tropicalized Quartics and Canonical Embeddings for Tropical Curves of Genus 3*
- Jorge Alberto Olarte, *The Moduli Space of Harnack Curves in Toric Surfaces*
- Anton Leykin, *Beyond Polyhedral Homotopies*
- Sandra di Rocco, *Higher Order Gauss Maps for Lattice Configurations*
- Dima Grigoriev, *Tropical Combinatorial Nullstellensatz and Sparse Polynomials*
- Stéphane Gaubert, *Condition Numbers in Nonarchimedean Semidefinite Programming and their Relation with Stochastic Mean Payoff Games*
- Timo de Wolff, *The Lattice of Amoebas*
- Alexander Esterov, *Galois Theory for Systems of Equations, and Small Polytopes*
- Christian Haase, *The Kingman Coalescent as a Density on a Space of Trees*

We also had a problem session in which questions concerning the smooth tropicalization of curves, volume and integer points of polytopes, points in Minkowski sums of faces of polytopes, eigenvalues of tropical exterior powers of matrices, identities in the semigroup of tropical matrices and plabic graphs and tropical Grassmannians were discussed.
Moduli spaces of curves and mirror symmetry
March 19–23

- Sara Angela Filippini, Stability Data, Irregular Connections and Tropical Curves
- Andreas Gross, Tropical Jacobians, Theta Divisors, and the Poincaré Formula
- Walter Gubler, Lagerberg’s Superforms and Non-archimedean Arakelov Theory
- Lionel Lang, Monodromy Groups of Lattice Polygons
- Sam Payne, Homology of Moduli Spaces of Curves
- Andrea Petracci, Mirror Symmetry and Fano Varieties
- Karin Schaller, Stringy Invariants and Combinatorial Identities
- Arthur Renaudineau, Bounding Betti Numbers of Real Hypersurfaces Near the Tropical Limit
- Grisha Mikhalkin, Maximally Writhed Real Algebraic Knots and Links
- Hannah Markwig, Tropical Mirror Symmetry for Elliptic Curves and Beyond
- Kristin Shaw, The Separating Semigroup of a Real Curve
- Philipp Jell, Lefschetz 1, 1-Theorem in Tropical Geometry
- Erwan Brugallé, On Betti Numbers of Tropical Varieties
- Grisha Mikhalkin, An Introductory Talk on Tropical Curves and Their Moduli Spaces
- Josephine Yu, Some Topics in Real Tropical Geometry
- Johannes Rau, Lower Bounds and Asymptotics of Real Double Hurwitz Numbers
- Ilya Tyomkin, Algebraic-tropical Correspondence for Rational Curves
- Eugenii Shustin, Geometry of the Tropical Cuspidal Edge

Tropical geometry and amoebas in higher dimension
April 16–20

- Frank Sottile, Describing Amoebas
- August Tsikh, On the Structure and Amoebas of Discriminants
- Johannes Nicaise, A Motivic Fubini Theorem for the Tropicalization Map
- Yue Ren, Tropical Basis Verification
- Lionel Lang, An Analogue of Hilbert’s Sixteen Problem for Amoebas
- Annette Werner, Tropical Geometry of the Hodge Bundle
- Anders Björner, Geometric Lattices, Discrete and Continuous
- Bernd Sturmfels, The Geometry of Gaudsoids
- June Huh, Kazhdan–Lusztig Theory for Matroids
- Bo Lin, The Combinatorics of the Tropical Hodge Bundles
- Benjamin Schröter, The Correlation Constant of a Field
- Kristin Shaw, Bounding Betti Numbers of Patchworked Real Hypersurfaces by Hodge Numbers
- Jonathan Wise, Tropical Data in Algebraic Moduli Problems
- Kiran Kedlaya, Tropical Geometry of Cluster Varieties: A Question from Number Theory
- Grigory Mikhalkin, Examples of Tropical-to-Lagrangian Correspondence
- Philipp Jell, Smooth Mumford Curves Admit Smooth Tropicalizations
- Jens Forsgård, Tropical Singularities
- Melody Chan, Cohomology of \( \text{M}_g \) and the Tropical Moduli Space of Curves
- Oleg Viro, Non-tropical Patchworking and Three Tropical Kingdoms
- Alex Fink, Constructions of Tropical Ideals
- Sam Payne, On the Kodaira Dimension of \( \text{M}_{23} \)
- Kalina Mincheva, The Picard Group of a Tropical Toric Scheme
- Erwan Brugallé, A Generalization of Haas Theorem
- Arthur Renaudineau, Number of Connected Components of Patchworked Real Plane Curves
- Diane Maclagan, An Update on Tropical Schemes
- Ilia Itenberg, Lines on Quartic Surfaces
- Renzo Cavalieri, On the Generating Function for Mumford’s Kappa Classes
SEMINARS

In the non-workshop weeks, we had seminar talks on Tuesday and Thursday afternoons. We started off with two talks per week but had to increase the frequency to three talks per week in certain weeks with especially many interesting guests around.

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**JANUARY 16 14:00–15:00**
Dhruv Ranganthan, Massachusetts Institute of Technology, MIT, *Moduli Spaces in Tropical Geometry*

**JANUARY 18 14:00–15:00**
Ralph Morrison, Williams College, Williamstown, *Tropical Graphs in the Plane*

**JANUARY 30 14:00–15:00**
Georg Loho, TU – Technische Universität Berlin, *Abstract Tropical Linear Programming and Matching Fields*

**FEBRUARY 1 14:00–15:00**
Chi Ho Yuen, Georgia Institute of Technology, *The Combinatorics of Break Divisors*

**FEBRUARY 6 14:00–15:00**
Guus Bollen, Eindhoven University of Technology, *The Lindström Valuation of an Algebraic Matroid Representation*

**FEBRUARY 6 15:30–16:30**
Timur Sadykov, Russian University of Economics, *Compactified and Polyhedral Versions of the Amoeba of an Algebraic Hypersurface*

**FEBRUARY 8 14:00–15:00**
Alejandro Vargas, University of Bern, *Tropical Morphisms to Metric Trees*

**FEBRUARY 13 14:00–15:00**
Nikita Kalinin, HSE St. Petersburg, *Laboratory of Game Theory and Decision Making, Tropical Series*

**FEBRUARY 15 14:00–15:00**
Jeffrey Giansiracusa, Swansea University, *A Moduli Perspective on Grassmannians and Matroids in Idempotent Algebra*

---

**FEBRUARY 27 14:00–15:00**
Michal Lason, University of Bern, *On Some Structures on Matroids and Related Algebraic Problems*

**FEBRUARY 27 15:30–16:30**
Milena Hering, University of Edinburgh, *Frobenius Splittings of Toric Varieties*

**MARCH 1 14:00–15:00**
Rudi Pendavingh, Eindhoven University of Technology, *Field Extensions, Derivations, and Matroids Over Skew Hyperfields*

**MARCH 6 14:00–15:00**
Maria Angelica Cueto, Ohio State University, *Anticanonical Tropical del Pezzo Cubic Surfaces Contain Exactly 27 Lines*

**MARCH 8 14:00–15:00**
Dustin Cartwright, University of Tennessee, *Construction of Lindström Valuations of Algebraic Extensions*

**MARCH 8 15:30–16:30**
Man-Wai Cheung, Harvard University, *Quiver Representations and Theta Functions*

**MARCH 13 14:00–15:00**
Jenia Tevelev, University of Massachusetts, *Lines and Points on the (Tropical) Plane*

**MARCH 13 15:30–16:30**
Joe Rabinoff, Georgia Institute of Technology, *Analytic and Tropical Theta Functions*

**MARCH 15 14:00–15:00**
Ilia Zharkov, Kansas State University, *Immersed Spheres in Phase Tropical Hypersurfaces*

**MARCH 27 14:00–15:00**
Lucia Lopez de Medrano, UNAM, *Planar Tropical Cubic Curves of Any Genus and Some Generalizations*
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<td>Hulya Arguz, Imperial College London</td>
<td>Tropical and Log Corals on the Tate Curve With a View Toward Symplectic Cohomology</td>
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<td>MARCH 29</td>
<td>14:00–15:00</td>
<td>Martin Ulirsch, University of Michigan</td>
<td>Tropical Geometry of the Hodge Bundle</td>
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<td>APRIL 3</td>
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<td>Tyler Foster, Max Planck Institute for Math.</td>
<td>Asymptotics of Short Intervals on Curves over Finite Fields</td>
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<td>APRIL 3</td>
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<td>Janko Böhm, TU Kaiserslautern</td>
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<td>APRIL 5</td>
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<td>Andres Jaramillo Puentes, Pierre-and-Marie-C</td>
<td>Trigonal Morsifications on Hirzebruch Surfaces</td>
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<td>APRIL 10</td>
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<td>Mounir Nisse, KIAS, Korea Institute for Adv.</td>
<td>Some Geometric and Topological Properties of (co)Amoebas</td>
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<td>APRIL 12</td>
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<td>Luis Felipe Tabera, Universidad de Cantabria</td>
<td>Multiple Points, Tropical Severi Varieties and the Casas Alvero Conjecture</td>
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<td>APRIL 24</td>
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<td>Benoit Bertrand, I.U.T. de Tarbes</td>
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<td>John Christian Ottem, University of Oslo</td>
<td>The Integral Hodge Conjecture for 3-folds</td>
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<td>Jonathan Wise, University of Colorado at B.</td>
<td>The Logarithmic Picard Group and its Tropicalization</td>
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PREPRINTS

Participants of the program were encouraged to submit preprints with results that were obtained during their visit to Institut Mittag-Leffler. Files of the preprints listed below can be found on our web site www.mittag-leffler.se.

Xavier Allamigeon, Stéphane Gaubert, Ricardo Katz, Mateusz Skomra: Condition Numbers of Stochastic Mean Payoff Games and What They Say About Nonarchimedean Semidefinite Programming.

Elizabeth Baldwin, Paul Klemperer: Understanding Preferences: Demand Types, and the Existence of Equilibrium with Indivisibilities.

Arthur Bik, Jan Draisma, Rob Eggermont: Polynomials and Tensors of Bounded Strength.

Janko Böhm, Christoph Goldner, Hannah Markwig: Tropical Mirror Symmetry in Dimension One.

Janko Böhm, Christoph Goldner, Hannah Markwig: Counts of Tropical Curves in E x P1 and Feynman Integrals.

Guus Bollen, Dustin Cartwright, Jan Draisma: Matroids Over One-dimensional Groups.

Emanuele Delucchi, Linard Hoessly: Fundamental Polytopes of Metric Trees Via Hyperplane Arrangements.

Emanuele Delucchi, Linard Hoessly, Elia Saini: Realization Spaces of Matroids Over Hyperfields.

Timo de Wolff, Mareike Dressler, Adam Kurpisz: Optimization Over the Boolean Hypercube via Sums of Nonnegative Circuit Polynomials.

Jan Draisma, Michal Lason, Anton Leykin: Stillman’s Conjecture Via Generic Initial Ideals.

Jan Draisma, Johannes Rau, Chi Ho Yuen: The Dimension of An Amoeba.

Jens Forsgård: Defective Dual Varieties for Real Spectra.


Christoph Goldner: Counting Tropical Rational Curves with Cross-ratio Constraints.

Marvin Anas Hahn, Hannah Markwig, Yue Ren, Ilya Tyomkin: Tropicalized Quartics and Canonical Embeddings for Tropical Curves of Genus 3.

Simon Hampe, Michael Joswig, Benjamin Schröter: Algorithms for Tight Spans and Tropical Linear Spaces.

Philipp Jell: Constructing Smooth and Fully Faithful Tropicalizations for Mumford Curves.

Philipp Jell, Claus Scheiderer, Josephine Yu: Real Tropicalization and Analytification of Semialgebraic Sets.

Marianne Johnson, Ngoc Mai Tran: Geometry and Algorithms for Upper Triangular Tropical Matrix Identities.


Mounir Nisse, Sottile Frank: Describing Amoebas.

Johannes Rau: Lower Bounds and Asymptotics of Real Double Hurwitz Numbers.

Benjamin Schröter: The Correlation Constant of a Field.

Michael Joswig, Ben Smith: Convergent Puiseux Series and Tropical Geometry of Higher Rank.

PARTICIPANTS

Karim Adiprasito, The Hebrew University of Jerusalem, Jerusalem, Israel

Marianne Akian, Inria, Ecole Polytechnique, Paris, Palaiseau, France

Hulya Arguz, Imperial College London, London, United Kingdom

Farhad Babaee, Université de Fribourg, Fribourg, Switzerland

Spencer Backman, The Hebrew University of Jerusalem, Jerusalem, Israel

Elizabeth Baldwin, University of Oxford, Oxford, United Kingdom

Benoit Bertrand, I.U.T. de Tarbes, Tarbes, France

Frederic Bihan, Université de Savoie, Le Bourget-du-Lac, Le Bourget-du-Lac, France

Guus Bollen, Eindhoven University of Technology, Eindhoven, Netherlands

Madeline Brandt, University of California, Berkeley, Berkeley, USA

Erwan Brugallé, Université de Nantes, Nantes Cedex 3, France

Janko Böhm, TU Kaiserslautern, Kaiserslautern, Germany

Dustin Cartwright, University of Tennessee, Knoxville, USA

Renzo Cavalieri, Colorado State University, Fort Collins, USA

Melody Chan, Brown University, Rhode Island, USA

Man-Wai Cheung, Harvard University, Cambridge, USA

Francisco Criado Gallart, TU – Technische Universität Berlin, Berlin, Germany

Maria Angelica Cueto, Ohio State University, Columbus, USA

Timo de Wolff, TU – Technische Universität Berlin, Berlin, Germany

Emanuele Delucchi, Université de Fribourg, Fribourg, Switzerland

Alicia Dickenstein, Universidad de Buenos Aires, Buenos Aires, Argentina

Jan Draisma, University of Bern, Bern, Switzerland

Antoine Ducros, University Pierre et Marie Curie, Paris, France

Boulos El Hilany, Universität Tübingen, Tübingen, Germany

Alexander Esterov, National Research University Higher School of Economics, Moscow, Russian Federation

Lorenzo Fantini, Institut Mathematiques de Jussieu, Paris, France
Discussions during Tropical Geometry, Amoebas and Polytopes.

Sara Angela Filippini, Imperial College London, London, United Kingdom
Alex Fink, Queen Mary University of London, London, United Kingdom
Jens Forsgård, University of Geneva, Geneva, Switzerland
Tyler Foster, Max Planck Institute for Mathematics, Bonn, Germany
Stephane Gaubert, Inria, Ecole Polytechnique, Paris, Palaiseau France
Jeffrey Giansiracusa, Swansea University, Swansea, United Kingdom
Christoph Goldner, Universität Tübingen, Tübingen, Germany
Dima Grigoriev, CNRS, Institut des Mathématiques de Lille, Lille, France

Andreas Gross, Imperial College London, London, United Kingdom
Walter Gubler, Universität Regensburg, Regensburg, Germany
Alexander Guterman, Lomonosov Moscow State University, Moscow, Russian Federation
Paul Görlich, Max Planck Institute Leipzig, Leipzig, Germany
Christian Haase, Freie Universität Berlin, Berlin, Germany
Marvin Hahn, Universität Tübingen, Tübingen, Germany
Milena Hering, University of Edinburgh, Edinburgh, United Kingdom
David Holmes, Universiteit Leiden, Leiden, Netherlands
June Huh, Institute for Advanced Study, IAS, New Jersey, USA
Ilia Itenberg, Institut de Mathématiques de Jussieu – Paris Rive Gauche, Paris
Tropical Geometry, Amoebas and Polytopes.

Zur Izhakian, University of Aberdeen, Aberdeen, United Kingdom
Andres Jaramillo Puentes, Tel Aviv University, Tel Aviv, Israel
Philipp Jell, Universität Regensburg, Regensburg, Germany
Dave Jensen, University of Kentucky, Lexington, USA
Anders Jensen, Aarhus University, Aarhus, Denmark
Marianne Johnson, University of Manchester, Manchester, United Kingdom
Michael Joswig, TU – Technische Universität Berlin, Berlin, Germany
Nikita Kalinin, HSE St. Petersburg, Laboratory of game theory and decision making, St Petersburg, Russian Federation
Mark Kambites, University of Manchester, Manchester, United Kingdom
Kiran Kedlaya, University of California, San Diego, La Jolla, USA
Gary Kennedy, Ohio State University, Columbus, USA
Ayush Kumar Tewari, Universität Tübingen, Tübingen, Germany
Max Kutler, Yale University, New Haven, USA
Sara Lamboglia, University of Warwick, Coventry, United Kingdom
Lionel Lang, Stockholm University, Stockholm, Sweden
Michal Lason, University of Bern, Bern, Switzerland
Yoav Len, Fields Institute, University of Toronto, Toronto, Canada
Anton Leykin, Georgia Institute of Technology, Atlanta, USA
Bo Lin, University of Texas at Austin, Austin, USA
Georg Loho, TU – Technische Universität Berlin, Berlin, Germany
Lucia Lopez de Medrano, UNAM, Mexico, Mexico
Diane Maclagan, University of Warwick, Coventry, United Kingdom
Gregorio Malajovich, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil
Hannah Markwig, Universität Tübingen, Tübingen, Germany
Thomas Markwig, Universität Tübingen, Tübingen, Germany
Margarida Melo, Universita Roma Tre, Rome, Italy
Grigory Mikhalkin, University of Geneva, Geneva, Switzerland
Kalina Mincheva, Yale University, New Haven, USA
Ralph Morrison, Williams College, Williamstown, USA
Johannes Nicaise, Imperial College London, London, United Kingdom
Mounir Nisse, KIAS, Korea Institute for Advanced Study, Seoul, Republic of Korea
Jorge Alberto Olarte, Freie Universität Berlin, Berlin, Germany
John Christian Ottem, University of Oslo, Oslo, Norway
Marta Panizzut, TU – Technische Universität Berlin, Berlin, Germany
Sam Payne, Yale University, New Haven, USA
Rudi Pendavingh, Eindhoven University of Technology, Eindhoven, Netherlands
Andrea Pettracci, University of Nottingham, Nottingham, United Kingdom
Joe Rabinoff, Georgia Institute of Technology, Atlanta, USA
Dhruv Ranganathan, Massachusetts Institute of Technology, MIT, Cambridge, USA
Johannes Rau, Universität Tübingen, Tübingen, Germany
Yue Ren, Max Planck Institute Leipzig, Leipzig, Germany
Arthur Renaudineau, Universität Tübingen, Tübingen, Germany
Felipe Rincon, University of Oslo, Oslo, Norway
Louis Rowen, Bar-Ilan University, Ramat-Gan, Israel
Helge Ruddat, Johannes Gutenberg-Universität Mainz, Mainz, Germany
Timur Sadykov, Russian University of Economics, Moscow, Russian Federation
Raman Sanyal, Goethe University Frankfurt am Main, Frankfurt am Main, Germany
Karim Schaller, Universität Tübingen, Tübingen, Germany
Benjamin Schröter, TU – Technische Universität Berlin, Berlin, Germany
Kristin Shaw, University of Oslo, Oslo, Norway
Eugenii Shustin, Tel Aviv University, Tel Aviv, Israel
Jeff Sommars, University of Illinois at Chicago, Chicago, USA
Alejandro Soto, Universität Tübingen, Tübingen, Germany
Frank Sottile, Texas A&M University, College Station, USA
Bernd Sturmfels, University of California, Berkeley, Berkeley USA
Luis Felipe Tabera, Universidad de Cantabria, Santander, Spain
Jenia Tevelev, University of Massachusetts Amherst, Amherst, USA
Thorsten Theobald, Goethe University Frankfurt am Main, Frankfurt am Main, Germany
Ngoc Mai Tran, Hausdorff Center for Mathematics, Bonn, Germany
Bach Tran, University of Edinburgh, Edinburgh, United Kingdom
August Tsikh, Siberian Federal University, Krasnoyarsk, Russian Federation
Ilya Tyomkin, Ben Gurion University of the Negev, Be’er Sheva, Israel
Martin Ulirsch, University of Michigan, Ann Arbor, USA
Alejandro Vargas, University of Bern, Bern, Switzerland
Annette Werner, Goethe University Frankfurt am Main, Frankfurt am Main, Germany
Jan Verschelde, University of Illinois at Chicago, Chicago, USA
Oleg Viro, Stony Brook University, Stony Brook, USA
Jonathan Wise, University of Colorado at Boulder, Boulder, USA

Josephine Yu, Georgia Institute of Technology, Atlanta, USA
Chi Ho Yuen, Georgia Institute of Technology, Atlanta, USA
Ilia Zharkov, Kansas State University, Manhattan, USA
SCIENTIFIC REPORT

THE OVERALL SET UP

The fall semester, September 3 to December 14, was dedicated to the area of mathematical biology. This broad field was divided into four month-long subfields: morphogenesis, collective behavior, population dynamics and cancer models. This meant that we scaled up from cellular behavior in pattern formation, via collective behavior of cells and larger agent such as guppy, to population dynamics over generations and continents. In the final two weeks, tools from the previous months were used to address questions regarding cancer and its possible treatments.

A lot of informal groups were also spontaneously formed such as the wound healing group denoted “Finding closure” and “Due pesci” studying a minimal school of fish, namely data from a pair of guppies in a circular tank.

DAILY WORK

The most common comment from the new participants to the organizers were: ”I did not know how great this place is. If I knew, I would have tried harder to stay longer.” Since this is the first theme semester on mathematical biology, Institut Mittag-Leffler is not so well known within the Mathematical Biology community. This has now changed.

Except for the workshops described below, we arranged three seminars a week, Tuesday to Thursday, 2–3 pm, see the list at the end.

WORKSHOPS

During the semester two workshops were set up: 1010 – The Maths of Biology, October 8–12 and Days on Multiscale Modelling in Tissue and Cancer Growth, December 10–11.

Public talks at the Royal Swedish Academy of Sciences, Mathematical Biology 10/10:

• Samuli Siltanen, The Magic of Math: X-ray Vision
• Jacob G Scott and Philip Gerlee: Using Game Theory to Understand the Rules of Tumor Evolution
• Michael Bonsall: Scaling the Heights of Biology … With Maths
• Julia Gog: Maths vs Disease
• David Sumpter: From Fish to Football: What Mathematics Can Teach us About Teamwork

Days on Multiscale Modelling in Tissue and Cancer Growth

Cancer Growth and Tissue Formation are two biological processes that, despite their apparent differences, share many biological similarities, e.g. in cell proliferation and differentiation during early embryonic development, in cell invasiveness and metabolism, in epigenetic regulation, gene expression and more. As a result, they are often studied in tandem, and it is expected that
understanding one will help decipher the other, and eventually beat cancer.

These biological processes are extremely complex and are studied by a multitude of disciplines, including Medical Sciences, Biology, Chemistry, Physics, Computer Science, and Mathematics. The contribution of Mathematics is primarily with the mathematical modelling, the model analysis, the development of the corresponding numerical methods, their numerical analysis, and the simulation of biological experiments. Moreover, Mathematics contributes by providing the necessary toolset to address the relevant multiple scales.

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**SEMINARS**

**SEPTEMBER 4 14:00–14:45**  
Pierre Degond, Imperial College London, *Tissue Self-Organization Through Mechanical Feedback*

**SEPTEMBER 5 14:00–14:45**  
Roeland Merks, Universiteit Leiden, *The Mathematics of Blood Vessel Growth: Predicting Multicellular Patterning from Individual Cell Behavior*

**SEPTEMBER 6 14:00–14:45**  
Rafael Bailo, Imperial College London, *Pedestrian Models Based on Rational Behaviour*

**SEPTEMBER 11 14:00–14:45**  
Jingwei Hu, Purdue University, *Asymptotic-preserving and Positivity-preserving Numerical Methods for a Class of Stiff Kinetic Equations*
SEPTEMBER 12 15:00–15:45
Yu Ernest Liu, University of Groningen, Modelling the Origin of Self-replication

SEPTEMBER 13 14:00–14:45
Linus Schumacher, University of Edinburgh, Common Behavioral Mechanisms Underlie Aggregation and Swarming of C. Elegans Nematode Worms

SEPTEMBER 14 14:00–14:45
Pedro Aceves-Sanchez, Imperial College London, Emergence of Vascular Networks

SEPTEMBER 17 14:00–14:45
Fred Vermolen, Delft University of Technology, Cell-based and Continuum-scale Models for the Contraction of Burns

SEPTEMBER 18 14:00–14:45
Philip Maini, University of Oxford, Mathematical Modelling of Angiogenesis

SEPTEMBER 19 14:00–14:45
Alexander Fletcher, University of Sheffield, Planar Polarity in Epithelial Morphogenesis

SEPTEMBER 20 14:00–14:45
Julia Gog, University of Cambridge, Some Topics in Infectious Disease Modelling

SEPTEMBER 21 14:00–14:45
Fengzhu Sun, University of Southern California, New Development in Alignment-free Genome and Metagenome Comparison

SEPTEMBER 24 14:00–14:45
Jeremy Gunawardena, Harvard Medical School, Are There Theorems in Biology?

SEPTEMBER 25 14:00–14:45
Andreas Deutsch, TU – Technische Universität Dresden, Biological Lattice-gas Cellular Automaton Models for the Analysis of Collective Effects in Cancer Invasion

SEPTEMBER 26 13:00–13:45
Georgy Kitavtsev, University of Oxford, Modelling Cell Motility as an Active Liquid Crystal Film with Moving Free Boundaries

SEPTEMBER 27 14:00–14:45
Magnus Lindh, Stockholm University, Evolution of Plants in a Water Limited Environment

OCTOBER 2 14:00–14:45
Mats Gyllenberg, University of Helsinki, ODE-reducibility of Structured Population Models

OCTOBER 3 14:00–14:45
Charlotte Hemelrijk, University of Groningen, Self Organization and Social Complexity in Primates

OCTOBER 4 14:00–14:45
Daniel Strömbom, Swansea University, Collective Motion from Local Attraction and Non-standard Modeling Assumptions

OCTOBER 5 14:00–14:45
Maria Bruna, University of Oxford, Diffusion of Particles With Short-range Interactions
OCTOBER 16 14:00–14:45
Maria-Rita D’Orsogna, California State University, Northridge, Science for the Greater Good: How a Math Professor Saved the Italian Coastline From Big Oil

OCTOBER 17 14:00–14:45
Emeric Bouin, CEREMADE, The Cane Toads Equation

OCTOBER 18 14:00–14:45
Theodore Kolokolnikov, Dalhousie University, Mathematics of Emergent Behaviour

OCTOBER 24 14:00–14:45
Pasquale Ciarletta, Polytechnic University of Milan, Mathematics for Personalized Neuro-oncology

OCTOBER 25 14:00–14:45
Bernt Wennberg, Chalmers/University of Gothenburg, Anticipation in Collective Motion

OCTOBER 26 14:00–14:45
Larisa Beilina, Chalmers/University of Gothenburg, Mathematical Modelling of HIV Infection: an Overview. Parameter Identification in Mathematical Model of HIV Infection With Drug Therapy

OCTOBER 30 14:00–14:45
Åke Brännström, Umeå University, Adaptive Dynamics for Spatially-structured Populations

OCTOBER 31 14:00–14:45
Robert Planqué, Vrije Universiteit Amsterdam, Maximising Microbial Growth Rate in Changing Environments

NOVEMBER 1 14:00–14:45
Björn Birnir, University of California, Santa Barbara, The Soliton in Angiogenesis

NOVEMBER 6 14:00–14:45
Alexander Nestor-Bergmann, University of Cambridge, Stress and Disorder in a Confluent Epithelium

NOVEMBER 7 14:00–14:45
Mark Lewis, University of Alberta, Generational Spreading Speeds for Integrodifference Equations

NOVEMBER 8 14:00–14:45
Philipp Getto, TU – Technische Universität Dresden, Delay Differential Equations Describing the Maturation of Cell Populations

NOVEMBER 13 14:00–14:45
Odo Diekmann, Utrecht University, The Winner Takes It All: How Semelparous Insects Can Become Periodical

NOVEMBER 14 14:00–14:45
Hans Metz, Universiteit Leiden, Conditions for the ODE Reducibility of Physiologically Structured Population Models
<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOVEMBER 15</td>
<td>14:00–14:45</td>
<td>Gael Raoul, CMAP, Centre de Mathématiques</td>
<td>Dynamics of a Spatially Structured Population Facing Climate Change</td>
</tr>
<tr>
<td>NOVEMBER 20</td>
<td>14:00–14:45</td>
<td>Kalle Parvinen, University of Turku</td>
<td>Evolution of Dispersal in Metapopulation Models</td>
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<tr>
<td>NOVEMBER 21</td>
<td>14:00–14:45</td>
<td>Peter Jagers, Chalmers/University of Gothenburg</td>
<td>How Might A Population Have Started and Where Is It Heading?</td>
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<tr>
<td>NOVEMBER 23</td>
<td>14:00–14:45</td>
<td>Vladimir Kozlov, Linköping University</td>
<td>Dynamical Behaviour of SIR Model With Co-infection of Two Viruses</td>
</tr>
<tr>
<td>NOVEMBER 27</td>
<td>14:00–15:00</td>
<td>Tom Britton, Stockholm University</td>
<td>Directed Preferential Attachment Models</td>
</tr>
<tr>
<td>NOVEMBER 27</td>
<td>15:00–16:00</td>
<td>Zuzanna Szymanska, University of Warsaw</td>
<td>Mathematical Modelling of the Process of Fibrous Connective Tissue Healing</td>
</tr>
<tr>
<td>NOVEMBER 28</td>
<td>14:00–14:45</td>
<td>Sergei Fedotov, University of Manchester</td>
<td>Anomalous Intracellular Transport, Cumulative Inertia and Aggregation in Scale-free Network</td>
</tr>
<tr>
<td>DECEMBER 4</td>
<td>14:00–14:45</td>
<td>Anna Marciniak-Czochra, Heidelberg University</td>
<td>Post-Turing Tissue Pattern Formation: Insights From Mathematical Modelling</td>
</tr>
<tr>
<td>DECEMBER 5</td>
<td>14:00–14:45</td>
<td>Stephen Kissler, Queens’ College</td>
<td>Identifying the Geographic Transmission Hubs of the 2009 A/H1N1pdm Influenza Pandemic in the United States</td>
</tr>
<tr>
<td>DECEMBER 6</td>
<td>14:00–14:45</td>
<td>Alexander Anderson, Moffitt Cancer Center</td>
<td>Adaptive Therapy for Metastatic Cancer: Mechanism vs Machine</td>
</tr>
<tr>
<td>DECEMBER 6</td>
<td>15:00–15:45</td>
<td>Hans Othmer, University of Minnesota</td>
<td>A Model for the Hippo Pathway in the Drosophila Wing Disc</td>
</tr>
<tr>
<td>DECEMBER 12</td>
<td>14:00–14:45</td>
<td>Jean Clairambault, Inria</td>
<td>An Evolutionary View of Cancer With Perspectives in Therapeutics, Taking Drug Resistance Into Account</td>
</tr>
<tr>
<td>DECEMBER 13</td>
<td>14:00–14:45</td>
<td>Benoit Perthame, Sorbonne University</td>
<td>Some Equations of Mathematical Biology</td>
</tr>
</tbody>
</table>

**PREPRINTS**

- Georgy Kitavtsev, Roman Taranets: Long-time Behavior of Solutions to a Singular Heat Equation with an Application to Hydrodynamics, Roman Taranets

**PARTICIPANTS**

- Nils A. Baas, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
- Pedro Aceves-Sanchez, Imperial College London, London United Kingdom
- Andrew Adamatzky, UWE Bristol, Bristol, United Kingdom
- Michael Adeniyi, Lagos State Polytechnic Ikorodu, Lagos, Nigeria
- Hiroaki Aikawa, Hokkaido University, Sapporo, Japan
- Giacomo Albi, University of Verona, Verona, Italy
- Axel Almet, University of Oxford, Oxford, United Kingdom
- Alexander Anderson, Moffitt Cancer Center, Tampa, USA
- Arturo Araujo, Braintree Ltd, London, United Kingdom
- Rafael Bailo, Imperial College London, London, United Kingdom
- Frank Ball, University of Nottingham, Nottingham, United Kingdom
- Raquel Barreira, Instituto Politécnico de Setúbal, Setúbal, Portugal
- David Basanta, Moffitt Cancer Center, Tampa, USA
- Larisa Beilina, Chalmers/University of Gothenburg, Göteborg, Sweden
- Cecilia Berardo, University of Helsinki, Helsinki, Finland
- Andrew Bernoff, Harvey Mudd College, Claremont, USA
- Björn Birnir, University of California, Santa Barbara, Santa Barbara, USA
Barbara Boldin, University of Primorska, Koper, Slovenia
Michael Bonsall, University of Oxford, Oxford, United Kingdom
Emeric Bouin, CEREMADE, Paris Cedex 16, France
Tom Britton, Stockholm University, Stockholm, Sweden
Maria Bruna, University of Oxford, Oxford, United Kingdom
Åke Brännström, Umeå University, Umeå, Sweden
Cécile Carrère, University Pierre et Marie Curie, Paris, France
José A. Carrillo, Imperial College London, London, United Kingdom
Tyler Cassidy, McGill University, Montreal, Canada
Mark Chaplain, University of St Andrews, St Andrews, United Kingdom
Paramita Chatterjee, The Polish Academy of Sciences, Warsaw, Poland
Li Chen, University of Mannheim, Mannheim, Germany
Pasquale Ciarletta, Polytechnic University of Milan, Milano, Italy
Jean Clairambault, Inria, Le Chesnay, France
Maria-Rita D’Orsogna, California State University, Northridge, Northridge, USA
Daniel De Souza, University of Edinburgh, Edinburgh, United Kingdom

Pierre Degond, Imperial College London, London, United Kingdom
Frank den Hollander, Universiteit Leiden, Leiden, Netherlands
Andreas Deutsch, TU – Technische Universität Dresden, Dresden, Germany
Odo Diekmann, Utrecht University, Utrecht, Netherlands
Preeti Dubey, Loyola University Chicago, Chicago, USA
Raluca Eftimie, University of Dundee, Dundee, United Kingdom
Hesso Farhan, University of Oslo, Oslo, Norway
Sergei Fedotov, University of Manchester, Manchester, United Kingdom
Alexander Fletcher, University of Sheffield, Sheffield, United Kingdom
Eugenia Franco, University of Helsinki, Helsinki, Finland
Amic Frouvelle, CEREMADE, Paris Cedex 16, France
Irina Gainova, Sobolev Institute of Mathematics, Novosibirsk, Russian Federation
Philip Gerlee, Chalmers/University of Gothenburg, Göteborg, Sweden
Philipp Getto, TU – Technische Universität Dresden, Dresden, Germany

The fireplace with owls and Mittag-Leffler’s epigram.
James Glazier, Indiana University Bloomington, Bloomington, USA
Julia Gog, University of Cambridge, Cambridge, United Kingdom
Katrin Grunert, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Jeremy Gunawardena, Harvard Medical School, Boston, USA
Mats Gyllenberg, University of Helsinki, Helsinki, Finland
Linnea Gyllingberg, Uppsala University, Uppsala, Sweden
Siming He, University of Maryland, College Park, USA
Sophie Hecht, Imperial College London, London, United Kingdom
Charlotte Hemelrijk, University of Groningen, Groningen, Netherlands
Jingwei Hu, Purdue University, West Lafayette, USA
Peter Jagers, Chalmers/University of Gothenburg, Göteborg, Sweden
Henrik Jönsson, University of Cambridge, Cambridge, United Kingdom

Dante Kalise, Imperial College London, London, United Kingdom
Artem Kuznetchev, University of Oxford, Oxford, United Kingdom
Anais Khuong, The Francis Crick Institute, London, United Kingdom
Stephen Kissler, Queens’ College, Cambridge, United Kingdom
Georgy Kitavtsev, University of Oxford, Oxford, United Kingdom
Vaclav Klika, Czech Technical University in Prague, Prague, Czech Republic
Theodore Kolokolnikov, Dalhousie University, Halifax, Canada
Shigeru Kondo, Osaka University, Osaka, Japan
Vladimir Kozlov, Linköping University, Linköping, Sweden
Yvonne Krumbeck, University of Bath, Bath, United Kingdom
Jochen Kursawe, University of Manchester, Manchester, United Kingdom
Jenny Larsson, University of Sheffield, Sheffield, United Kingdom
Mark Lewis, University of Alberta, Edmonton, Canada
Magnus Lindh, Stockholm University, Stockholm, Sweden

A seminar given by Shigeru Kondo.
Gustav Lindwall, Chalmers/University of Gothenburg, Göteborg, Sweden
Yu Ernest Liu, University of Groningen, Groningen, Netherlands
Torbjörn Lundh, Chalmers/University of Gothenburg, Göteborg, Sweden
Anotida Madzvamuse, University of Sussex, Brighton, United Kingdom
Philip Maini, University of Oxford, Oxford, United Kingdom
Charamblos Makridakis, Institute of Applied and Computational Mathematics Foundation for Research and Technology – Hellas, Heraklion, Crete, Greece
Adam Malik, Chalmers/University of Gothenburg, Göteborg, Sweden
Anna Marciniak-Czochra, Heidelberg University, Heidelberg, Germany
Roeland Merks, Universiteit Leiden, Leiden, Netherlands
Hans Metz, Universiteit Leiden, Leiden, Netherlands
Hideki Murakawa, Kyushu University, Fukuoka, Japan
Alexander Nestor-Bergmann, University of Cambridge, Cambridge, United Kingdom
Daniel Nichol, The Institute of Cancer Research, London, United Kingdom
Qing Nie, University of California, Irvine, California, USA
Robert John Noble, ETH Zürich, Zürich, Switzerland
Max Ortiz Catalan, Chalmers/University of Gothenburg, Göteborg, Sweden
Hans Othmer, University of Minnesota, Minneapolis, USA
Kalle Parvinen, University of Turku, Turku, Finland
Benoit Perthame, University Pierre et Marie Curie, Paris, France
Robert Planqué, Vrije Universiteit Amsterdam, Amsterdam, Netherlands
Nastassia Pouradier Duteil, Université Paris-Dauphine, Paris, France
Luigi Preziosi, Politecnico di Torino, Torino, Italy
Mariya Ptashnyk, Heriot Watt University, Edinburgh, United Kingdom
Gael Raoul, CMAP, Centre de Mathématiques Appliquées – Ecole polytechnique, Palaiseau, France
Faustino Sánchez Garduño, Universidad Nacional Autónoma de México, Mexico City, Mexico
Francesca Scarabel, University of Helsinki, Helsinki, Finland
Christian Schmeiser, University of Vienna, Vienna, Austria
Markus Schmidtchen, Imperial College London, London, United Kingdom
Santiago Schnell, University of Michigan, Ann Arbor, USA
Linus Schumacher, University of Edinburgh, Edinburgh, United Kingdom
Jacob Scott, Cleveland Clinic, Cleveland, USA
Nikolaos Sfakianakis, Heidelberg University, Heidelberg, Germany
Samuli Siltanen, University of Helsinki, Helsinki, Finland
Wylie Stroberg, University of Michigan, Ann Arbor, USA
Daniel Strömberg, Swansea University, Swansea, United Kingdom
David Sumpter, Uppsala University, Uppsala, Sweden
Fengzhu Sun, University of Southern California, Los Angeles, USA
Christina Surulescu, Universität Kaiserslautern, Kaiserslautern, Germany
Alexander Szorkovszky, Institut Mittag-Leffler, Djursholm, Sweden
Zuzanna Szymanska, University of Warsaw, Warsaw, Poland
Eitan Tadmor, University of Maryland, College Park, USA
Min Tang, Shanghai Jiao Tong University, Shanghai, China
Pieter Trapman, Stockholm University, Stockholm, Sweden
Dumitru Trucu, University of Dundee, Dundee, United Kingdom
Jun Udagawa, Shiga University of Medical Science, Shiga, Japan
Chandrasekhar Venkataraman, University of Sussex, Brighton, United Kingdom
Bernt Wennberg, Chalmers/University of Gothenburg, Göteborg, Sweden
Fred Vermolen, Delft University of Technology, Delft, Netherlands
Alexandria Volkening, Mathematical Biosciences Institute, Columbus, USA
Mattia Zanella, Politecnico di Torino, Torino, Italy
Interfaces between Geometric Analysis and Mathematical Physics

May 7–11, 2018

Organizers: Bernhelm Booß-Bavnbek, Roskilde University; Matthias Lesch, University of Bonn; George Marinescu, University of Cologne; Boris Vertman, Carl von Ossietzky University of Oldenburg

Scientific Report

Our second conference at the Mittag-Leffler Institute, May 7–11, 2018 gathered physicists together with experts on central topics in geometric analysis with deep connections to mathematical physics. The meeting included highest level talks by leading researchers in the various fields and the following fundamental directions have increasingly crystallized:

1. Bergman Kernel Asymptotics, Quantum Hall Effect (Klevtsov, Ma, Marinescu, Savale, Zelditch)

2. Spectral Geometry and Index Theory on Stratified Spaces (Brüning, Lesch, Piazza, Rowlett, Schrohe, Vertman)

3. Mathematical Physics, Yang-Baxter Equation, QFT (Burban, Cattaneo, Güneysu, Nielsen, Petersen, Sorensen)

4. Hyperbolic Geometry, Waves & Index Theory on Space times (Baskin, Fedosova, Müller, Strohmeier)

5. Geometric Non-linear PDE, Mean Curvature and Ricci Flow (Krönke, Möller, Rowlett, Vertman)

6. Spectral Flow and Maslov Index (Booß, Lesch, Waterstraat, Zhu)

The presented ideas included central properties of singular manifolds and partial differential equations, e.g., regularity studies for (fractional) powers of pseudo-differential operators, the interrelations between the hypoelliptic Laplacian and statistical mechanics, integral equations of complex analysis, bifurcations for mildly non-linear equations, the statistics of critical points, the standard model of particle physics as a spectral triple in non-commutative geometry, generalizations of adiabatic limits, topological field theories and semiclassical limits.

There are strong connections between the individual research directions. On the interface between (1) and (2) the question of Bergman kernel asymptotics and Quantum Hall effect on spaces e.g., with conical singularities has developed into an increasingly
important question. On the interface between (2), (5), and (6) the question of geometric flows in singular configurations as well as formation of singularities has been a focal point of research for some years now. On the interface between (2), (3) and (4) various geometric questions in the setting of Minkowski and Lorentzian space times naturally provide a strong basis for joint research. These interfaces have been particularly highlighted by the following talks:

- **Savale, Nikhil**: Sub-Riemannian spectral geometry (Weyl law, trace formula, propagation, ergodicity) where new phenomena appear, such as Hausdorff dimension, abnormal geodesics. This can be used also to give the expansion of the Bergman kernel in a degenerate case.

- **Klevtsov, Ma, Zelditch**: Bergman kernels are generalized to symplectic manifolds, providing an embedding theorem and Berezin-Toeplitz quantization. They are successfully used in the study of various aspects of Quantum Hall Effect: filling up a domain with quantum states and their (partial) Bergman density, Gaussian interface along the boundary, a precise mathematical meaning of the long-standing conjecture, that the effective theory of the quantum Hall effect at large distances is described by the Chern-Simons theory, variation of the states on the moduli space of complex structures (physically highly relevant).

- **Petersen, Zelditch**: The Berezin-Toeplitz quantization plays an important role in the talks of Zelditch and in the asymptotic expansions of Witten-Reshetikhin-Turaev invariants.

- **Burban, Klevtsov**: Laughlin states are a guiding model in the study of fractional Hall Effect. Their mathematical understanding is still to be achieved. As a key ingredient, Fay’s identities play a central role in the physical applications. On the other hand, Fay’s identities are nothing but higher genus generalizations of the so-called associative Yang-Baxter equation. An important point in the talk of Burban is that singular Riemann surfaces are essential in the algebro-geometric study of Yang-Baxter equations.

- **Kröncke, Lesch**: Geometric analysis in the setting of compact stratified spaces has seen recent important advances, including characterization of domains, establishment of asymptotic resolvent expansions, geometric flows and extension of the APS index theorem in various singular settings.
As in the previous meeting, the inclusive framework provided a successful platform for intensive discussions and future collaborations. Important questions for future work were outlined and led to intense discussions, both in large and in small groups, and both between researchers with a mathematical and with a physical background. The conference provided another significant step towards bridging eventual gaps between physicists and mathematicians towards joint research. If possible, it should become an annual or bi-annual event developing a tradition and research program on its own.

**PARTICIPANTS**

Dean Baskin, Texas A&M University, College Station, USA  
Holger Bech Nielsen, Niels Bohr Institut, Copenhagen, Denmark  
Bernhelm Booß-Bavnbek, Roskilde University, Roskilde, Denmark  
Jochen Brüning, Humboldt-Universität zu Berlin, Berlin, Germany  
Igor Burban, University of Cologne, Cologne, Germany  
Alberto Cattaneo, University of Zurich, UZH, Zürich, Switzerland  
William Elbæk Petersen, Aarhus University, Aarhus, Denmark  
Ksenia Fedosova, University of Freiburg, Freiburg, Germany  
Batu Güneysu, Humboldt-Universität zu Berlin, Berlin, Germany  
Semyon Klevtsov, University of Cologne, Cologne, Germany  
Klaus Kröncke, Universität Hamburg, Hamburg, Germany  
Matthias Lesch, University of Bonn, Bonn, Germany  
Xiaonan Ma, Université Paris Diderot, Paris 7, Paris, France  
George Marinescu, University of Cologne, Cologne, Germany  
Werner Müller, University of Bonn, Bonn, Germany  
Niels Martin Møller, University of Copenhagen, Copenhagen, Denmark  
Paolo Piazza, Sapienza University of Rome, Roma, Italy  
Julie Rowlett, Chalmers/University of Gothenburg, Göteborg, Sweden  
Nikhil Savale, University of Cologne, Cologne, Germany  
Elmar Schrohe, Leibniz Universität, Hannover, Germany  
Alexander Strohmaier, University of Leeds, Leeds, United Kingdom  
Nils Waterstraat, University of Kent, Kent, United Kingdom  
Boris Vertman, Carl von Ossietzky University of Oldenburg, Oldenburg, Germany  
Steven Morris Zelditch, Northwestern University, Evanston, USA  
Peng Zhou, Institut des Hautes Études Scientifiques (IHÉS), Bures-sur-Yvette, France  
Chaofeng Zhu, Nankai University, Tianjin, China  
Thomas Østergaard Sørensen, LMU Ludwig-Maximilians-Universität München, München, Germany
The goal of the workshop was to bring together researchers with a common mathematical background in spectral analysis of partial differential operators, calculus of variations and functional inequalities. The conference was the fourth sequel in a series of events on “Low eigenvalues of Laplace and Schrödinger operators”, initiated at the American Institute of Mathematics Palo Alto in 2006, and later continued at the Oberwolfach Mathematical Institute in 2009 and at the Banff International Research Station in July 2013. It was therefore a great pleasure to meet this time at Institut Mittag-Leffler with about 40 participants from all over Europe, the US and Chile to discuss current developments in spectral theory.

During the workshop special attention was paid to such topics as semi-classical spectral estimates, shape optimization, Hardy-Sobolev inequalities and eigenvalues of magnetic and Pauli operators. Some of the talks covered new results on longstanding research topics, which have been present on the previous events as well, as for example, Cwikel-Lieb-Rosenblum and Lieb-Thirring bounds for Schrödinger operators, bound state estimates for magnetic operators and Pauli operators, eigenvalue bounds for the Laplacian with various boundary conditions, minimal partitions for eigenvalues of the Laplacian or eigenvalue bounds on graphs. On the other hand, new
interesting problems have been subject of talks, such as the spectral analysis of graphene quantum dots, scattering and resonances in waveguides with singular perturbations or new results on the entropy decay for the Kac evolution. The slides of a substantial part of the talks have been made available at the conference home page of the Institut Mittag-Leffler. The workshop was a very fruitful event with an intensive scientific discourse. The mixture of experienced and younger scientists has proven to be very productive. We are extremely grateful to Institut Mittag-Leffler for the outstanding working conditions during the workshop as well as for the smooth organization and very effective communication with the organizers.

PARTICIPANTS

Mark Ashbaugh, University of Missouri, Columbia, USA
Rafael D. Benguria, Pontificia Universidad Católica de Chile, Santiago, Chile
Gregory Berkolaiko, Texas A&M University, College Station, USA
Virginie Bonnaillie-Noël, ENS Paris, CNRS, Paris, France
Dorin Bucur, Université Savoie Mont Blanc, Chambéry, France
Horia Cornean, Aalborg University, Aalborg, Denmark
Gregory Berkolaiko, Texas A&M University, College Station, USA
Virginie Bonnaillie-Noël, ENS Paris, CNRS, Paris, France
Dorin Bucur, Université Savoie Mont Blanc, Chambéry, France
Horia Cornean, Aalborg University, Aalborg, Denmark
Gregory Berkolaiko, Texas A&M University, College Station, USA
Virginie Bonnaillie-Noël, ENS Paris, CNRS, Paris, France
Dorin Bucur, Université Savoie Mont Blanc, Chambéry, France
Horia Cornean, Aalborg University, Aalborg, Denmark
Francesco Della Pietra, Università degli studi di Napoli Federico II, Napoli, Italy
Jean Dolbeault, CEREMADE, Paris, France
Tomas Ekholm, KTH Royal Institute of Technology, Stockholm, Sweden
Pavel Exner, Nuclear Physics Institute ASCR, Prague 10, Czech Republic
Veronica Felli, University of Milano-Bicocca, Milano, Italy
Pedro Freitas, University of Lisbon, Lisbon, Portugal
André Froehly, Leibniz Universität, Hannover, Germany
Nunzia Gavitone, The University of Naples Federico II, Naples, Italy
Evans Harrell, Georgia Institute of Technology, Atlanta, USA
Bernard Helffer, Université de Nantes, Nantes Cedex 3, France
Dirk Hundertmark, Karlsruhe Institute of Technology, Karlsruhe, Germany
Bernd Kawohl, University of Cologne, Cologne, Germany
James Kennedy, University of Lisbon, Lisbon, Portugal
Hynek Kovarik, Università degli Studi di Brescia, Brescia BS, Italy
Pavel Kurasov, Stockholm University, Stockholm, Sweden
Robin Lang, University of Stuttgart, Stuttgart, Germany
Ari Laptev, Imperial College London, London, United Kingdom
Simon Larson, KTH Royal Institute of Technology, Stockholm, Sweden
Richard Laugesen, University of Illinois at Urbana-Champaign, Urbana, USA
Michael Loss, Georgia Institute of Technology, Atlanta, USA
Vladimir Lotoreichik, Czech Academy of Sciences, Rez, Czech Republic
Douglas Lundholm, KTH Royal Institute of Technology, Stockholm, Sweden
Benedetta Noris, Università de Picardie Jules Verne, Amiens, France
Konstantin Pankrashkin, Université Paris-Sud, Orsay, France
Nam Phan Thanh, LMU Munich, München, Germany
Gianpaolo Piscitelli, University of Lisbon, Lisbon, Portugal
Aldo Pratelli, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany
Tobias Ried, Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany
Jonathan Rohleder, Stockholm University, Stockholm, Sweden
Heinz Siedentop, LMU Ludwig-Maximilians-Universität München, München, Germany
Samuele Sottile, Lund University, Lund, Sweden
Susanna Terracini, University of Turin, Turin, Italy
Hanne Van Den Bosch, Universidad de Chile, Santiago de Chile, Chile
Timo Weidl, Institut für Analysis, Dynamik und Modellierung, Stuttgart, Germany
Semjon Wugalter, Karlsruhe Institute of Technology, Karlsruhe, Germany
Hausdorff Geometry of Polynomials and Polynomial Sequences

May 28–June 1, 2018

Organizers: Dmitry Khavinson, University of South Florida; Edward Saff, Vanderbilt University; Boris Shapiro, Stockholm University

SCIENTIFIC REPORT

Aims and Scope: This conference was a larger event following several small workshops on the topic of geometry of polynomials organized in the past years. (The previous workshops were supported by the Banff Research Center, the American Institute of Mathematics, the University of Cyprus, and the Bulgarian Academy of Sciences.) The talks were mainly devoted to the very recent results dealing with several aspects of univariate polynomials and polynomial sequences, including orthogonal polynomials, Polya-Schur theory, root localization problems, and Smale’s conjecture.

PARTICIPANTS

Per Alexandersson, KTH Royal Institute of Technology, Stockholm, Sweden
Yacin Ameur, Lund University, Lund, Sweden
Catherine Beneteau, University of South Florida, Tampa, USA
Petter Brändén, KTH Royal Institute of Technology, Stockholm, Sweden
Rikard Bögvad, Stockholm University, Stockholm, Sweden
Peter Dragnev, Purdue University Fort Wayne, Fort Wayne, USA
Maurice Duits, KTH Royal Institute of Technology, Stockholm, Sweden
Tamas Forgacs, Fresno State University, Fresno, USA
Jens Forsgård, University of Geneva, Geneva, Switzerland

The participants of Hausdorff Geometry of Polynomials and Polynomial Sequences.
Although spanning only a couple of days, the workshop was attended by two dozen experts, all interacting in a vibrant and emotional (due to the circumstances) atmosphere. While not all participants could speak, due to the tight schedule, we had a variety of extremely interesting and informative lectures covering cutting edge aspects of research in modern mathematical analysis, much of it inspired by the work of Serguei Shimorin.

All in all, the workshop was a success, and it is the deep belief of the organizers that the meeting reflected the rich spiritual soul of Serguei Shimorin and honored his memory and his many scientific achievements. Besides the many rich and dynamic scientific exchanges, the family of our late colleague Serguei Shimorin was present at a commemorative dinner event.

Björn Gustafsson, KTH Royal Institute of Technology, Stockholm, Sweden
Christian Hägg, Stockholm University, Stockholm, Sweden
Olga Katkova, Wheelock College, Boston, USA
Dmitry Khavinson, University of South Florida, Tampa, USA
Vladimir Kostov, Université de Nice – Sophia Antipolis, Nice, France
Alex Kreinin, IBM Research, Toronto, Canada
Jonathan Leake, University of California, Berkeley, Berkeley, USA
Myro Manolaki, University of South Florida, Tampa, USA
Andrei Martínez-Finkelshtein, Universidad de Almeria, Almeria, Spain
Gleb Nenashev, Massachusetts Institute of Technology, MIT, Cambridge, USA
Andrzej Piotrowski, University of Alaska Southeast, Juneau, USA
Mihai Putinar, University of California, Santa Barbara, Santa Barbara, USA
Mohan Ravichandran, Mimar Sinan University, Istanbul, Turkey
Edward Saff, Vanderbilt University, Nashville, USA
Blagovest Sendov, Bulgarian Academy of Sciences, Sofia, Bulgaria
Boris Shapiro, Stockholm University, Stockholm, Sweden
Alan Sola, Stockholm University, Stockholm, Sweden
Frantisek Stampach, Stockholm University, Stockholm, Sweden

Nikos Stylianopoulos, University of Cyprus, Nicosia, Cyprus
Milos Tater, Nuclear Physics Institute ASCR, Rez, Czech Republic
Patrick Tuen Wai Ng, The University of Hong Kong, Hong Kong
Mikhail Tyaglov, Shanghai Jiao Tong University, Shanghai, China
Anna Vishnyakova, Kharkov University, Kharkiv, Ukraine

Analysis of Operators on Function Spaces: A Conference Dedicated to the Mathematics of Serguei Shimorin

June 4–5, 2018

Organizers: Catherine Beneteau, University of South Florida; Håkan Hedenmalm, KTH Royal Institute of Technology; Dmitry Khavinson, University of South Florida; Mihai Putinar, University of California, Santa Barbara; Alan Sola, Stockholm University

SCIENTIFIC REPORT

Although spanning only a couple of days, the workshop was attended by two dozen experts, all interacting in a vibrant and emotional (due to the circumstances) atmosphere. While not all participants could speak, due to the tight schedule, we had a variety of extremely interesting and informative lectures covering cutting edge aspects of research in modern mathematical analysis, much of it inspired by the work of Serguei Shimorin.

All in all, the workshop was a success, and it is the deep belief of the organizers that the meeting reflected the rich spiritual soul of Serguei Shimorin and honored his memory and his many scientific achievements. Besides the many rich and dynamic scientific exchanges, the family of our late colleague Serguei Shimorin was present at a commemorative dinner event.
The participants of Analysis of Operators on Function Spaces: A Conference Dedicated to the Mathematics of Serguei Shimorin.

PARTICIPANTS

Evgenii Abakumov, Université Paris-Est Marne-la-Vallée Marne-la-Vallée Cedex 2, France

Alexandru Aleman, Lund University, Lund, Sweden

Anton Baranov, St Petersburg State University, St. Petersburg, Russian Federation

Catherine Beneteau, University of South Florida, Tampa, USA

Kelly Bickel, Bucknell University, Lewisburg, USA

Eva Gallardo Gutierrez, Complutense University of Madrid, UCM, Madrid, Spain

Håkan Hedenmalm, KTH Royal Institute of Technology, Stockholm, Sweden

Dmitry Khavinson, University of South Florida, Tampa, USA

Constanze Liaw, University of Delaware, Newark, USA

Annemarie Luger, Stockholm University, Stockholm, Sweden

Eugenia Malinnikova, NTNU – Norwegian University of Science and Technology, Trondheim, Norway

John McCarthy, Washington University in St. Louis, St. Louis, USA

Rajesh Pereira, University of Guelph, Ontario, Canada

Mihai Putinar, University of California, Santa Barbara, Santa Barbara, USA

Thomas Ransford, Université Laval, Québec, Canada

Stefan Richter, University of Tennessee, Knoxville, USA

William Ross, University of Richmond, Richmond, USA

Jaydeb Sarkar, Indian Statistical Institute, Bangalore, India

Daniel Seco, ICMAT, Institute of Mathematical Sciences, Madrid, Spain

Kristian Seip, NTNU – Norwegian University of Science and Technology, Trondheim, Norway

Alan Sola, Stockholm University, Stockholm, Sweden

Dmitry V. Yakubovich, Universidad Autónoma de Madrid, Madrid, Spain
The theory of nonlinear partial differential equations is of fundamental importance in mathematical analysis. A crucial role in understanding nonlinear phenomena is played by regularity estimates based only on the structure of the equation. Indeed, solutions of nonlinear PDEs, when they exist, might be not smooth. Over the last few decades a vast amount of research papers have been published and powerful techniques have been developed to understand these phenomena. Recent advances, some by participants in the workshop, have already turned out to be powerful enough to solve several previously unreachable problems and have opened a whole new area of research. This workshop focused on three themes related to nonlinear parabolic PDEs which have gained traction recently: boundary regularity, with the goal to discuss and provide a Wiener criterion for a wide class of nonlinear parabolic PDEs, nonlinear thermal capacity, with the goal to discuss and develop a nonlinear capacity theory for a wide class of nonlinear parabolic PDEs, and gradient estimates, with the goal to discuss and extend higher integrability results of the gradient for a wide class of nonlinear parabolic PDEs. This workshop gathered specialists and younger researchers working in this field of analysis. There were many young mathematicians who participated in the workshop. Most of the speakers were recent postdocs and PhD students. The total number of talks was kept small (two talks per day, morning and afternoon) in order to encourage informal discussions and interaction between participants. The remaining time was left for discussions and group work.
Gaussian Fields in Random Matrix Theory

June 18–21, 2018

Organizers: Maurice Duits, KTH Royal Institute of Technology, Stockholm and Vadim Gorin, Massachusetts Institute of Technology, MIT

Scientific Report

In recent years, Gaussian Fields were found to govern the asymptotic behavior of many observables in random matrix models. Special examples include the 2d Gaussian Free Fields appearing in the study of global fluctuations of linear statistics of eigenvalues, Gaussian Multiplicative Chaos showing up in the asymptotic of characteristic polynomials, and non-linear functionals of Brownian Motion describing local operator limits. The workshop succeeded in bringing together a balanced selection of experts from these areas of research. Apart from maintaining existing collaborations, the workshop gave ample opportunity for new collaborations and increased the interaction between experts from different areas.

The workshop lasted for four days with six talks each day. The first day concentrated on the recent progress in the study of characteristic polynomials of random matrices and multiplicative chaos. The second day was centered on random tilings of planar domains. Then on the third day the topic was beta ensembles and related models. Finally, the last day focused on Toeplitz determinants and gap probabilities. A highlight was the talk by Fyodorov with its truly interdisciplinary character. Encouraged by positive responses from the participants, preparations are being made for the organization of a similar (in style and topic) workshop sometime soon.
PARTICIPANTS

Gernot Akemann, Bielefeld University, Bielefeld, Germany
Nguyen Bao, KTH Royal Institute of Technology, Stockholm, Sweden
Tomas Berggren, KTH Royal Institute of Technology, Stockholm, Sweden
Jonathan Breuer, The Hebrew University of Jerusalem, Jerusalem, Israel
Alexey Bufetov, Massachusetts Institute of Technology, MIT, Cambridge, USA
Alexander Bufetov, Steklov Mathematical Institute, Moscow, Russian Federation
Christophe Charlier, KTH Royal Institute of Technology, Stockholm, Sweden
Sunil Chhita, Durham University, Durham, United Kingdom
Tom Claey, Université Catholique de Louvain, Louvain-la-Neuve, Belgium
Percy Deift, Courant Institute of Mathematical Sciences, New York, USA
Maurice Duits, KTH Royal Institute of Technology, Stockholm, Sweden
Benjamin Fahs, KTH Royal Institute of Technology, Stockholm, Sweden
Patrik Ferrari, University of Bonn, Bonn, Germany
Yan Fyodorov, King’s College London, London, United Kingdom
Vadim Gorin, Massachusetts Institute of Technology, MIT, Cambridge, USA
Diane Holcomb, KTH Royal Institute of Technology, Stockholm, Sweden
Kurt Johansson, KTH Royal Institute of Technology, Stockholm, Sweden
Rostyslav Kozhan, Uppsala University, Uppsala, Sweden
Igor Krasovsky, Imperial College London, London, United Kingdom
Arno Kuijlaars, KU Leuven, Leuven (Heverlee) Belgium
Gautier Lambert, University of Zurich, UZH, Zürich, Switzerland
Seung-Yeop Lee, University of South Florida, Tampa, USA
Yiting Li, KTH Royal Institute of Technology, Stockholm, Sweden
Harris Maroudas, Imperial College London, London, United Kingdom
Joseph Najnudel, University of Cincinnati, Cincinatti, USA
Thorsten Neuschel, Université Catholique de Louvain, Louvain-la-Neuve, Belgium
Ashkan Nikebaghli, University of Zurich, UZH, Zürich, Switzerland
Elliot Paquette, Ohio State University, Columbus, USA
Kevin Schnelli, KTH Royal Institute of Technology, Stockholm, Sweden
Tatyana Shcherbyna, Princeton University, Princeton, USA
Mykhaylo Shkolnikov, Princeton University, Princeton, USA
Nick Simm, University of Sussex, Brighton, United Kingdom
Christian Webb, Aalto University, Espoo, Finland
Ofer Zeitouni, Weizmann Institute of Science, Rehovot, Israel
The conference was held from June 25 to June 29, 2018. It was attended by around 40 participants, including people from the N-Cube network, invited speakers from abroad, and local attendees. During the conference we had 19 research talks. In a survey after the conference participants expressed that the quality and range of the talks was excellent, and the event generally was very well appreciated. We believe that the strength of our approach and of the network is to collect researchers that would generally not go to the same conferences and thereby to enable fruitful exchange of ideas. In principle three fields within number theory were covered: arithmetic geometry, analytical and probabilistic methods, and modular forms and Galois representations.

**ScienTific Report**

The **N-Cube Week**

**June 25–29, 2018**

*Organizers: Jonas Bergström, Stockholm University; Dennis Eriksson, Chalmers/University of Gothenburg; Lars Halvard Halle, University of Copenhagen; Pär Kurlberg, KTH Royal Institute of Technology*

**Participants**

Eric Ahlqvist, KTH Royal Institute of Technology, Stockholm, Sweden

Daniel Bergh, University of Copenhagen, Copenhagen, Denmark

Jonas Bergström, Stockholm University, Stockholm, Sweden

Olof Bergvall, Uppsala University, Uppsala, Sweden

Kirsti Biggs, University of Bristol, Bristol, United Kingdom

Julia Brandes, Chalmers/University of Gothenburg, Göteborg, Sweden

Jan Bruinier, Technical University of Darmstadt, Darmstadt, Germany

Juliusz Brzezinski, Chalmers/University of Gothenburg, Göteborg, Sweden

Chantal David, Concordia University, Sir George William Campus, Montreal, Canada
Dennis Eriksson, Chalmers/University of Gothenburg, Göteborg, Sweden
Anne-Maria Ernvall-Hytönen, Åbo Akademi, Åbo, Finland
Jessica Fintzen, University of Michigan, Ann Arbor, USA
Javier Fresan, École Polytechnique, Palaiseau Cedex, France
Wushi Goldring, Stockholm University, Stockholm, Sweden
Lars Halvard Halle, University of Copenhagen, Copenhagen, Denmark
Dennis Hejhal, University of Minnesota, Minneapolis, USA
Jeroen Hekking, KTH Royal Institute of Technology, Stockholm, Sweden
Sebastian Herrero, Chalmers/University of Gothenburg, Göteborg, Sweden
Andreas Holmström, Stockholm University, Stockholm, Sweden
Xia Jiacheng, Chalmers/University of Gothenburg, Göteborg, Sweden
Christian Johansson, University of Cambridge, Cambridge, United Kingdom
Ian Kiming, University of Copenhagen, Copenhagen, Denmark
Emmanuel Kowalski, ETH Zürich, Zürich, Switzerland
Simon Kristensen, Aarhus University, Aarhus, Denmark
Pär Kurlberg, KTH Royal Institute of Technology, Stockholm, Sweden
Daniel Larsson, HSN, University College of Southeast Norway, Norway
Stefano Marseglia, Stockholm University, Stockholm, Sweden
Niels Matthes, Kyushu University, Fukuoka, Japan
Lilian Matthiesen, KTH Royal Institute of Technology, Stockholm, Sweden
Johannes Nicaise, Imperial College London, London, United Kingdom
Fabien Pazuki, University of Copenhagen, Copenhagen, Denmark
Riccardo Pengo, University of Copenhagen, Copenhagen, Denmark
Tomas Persson, Lund University, Lund, Sweden
Daniel Persson, Chalmers/University of Gothenburg, Göteborg, Sweden
Dan Petersen, Stockholm University, Stockholm, Sweden
Martin Raum, Chalmers/University of Gothenburg, Göteborg, Sweden
Morten Risager, University of Copenhagen, Copenhagen, Denmark
David Rydh, KTH Royal Institute of Technology, Stockholm, Sweden
Per Salberger, Chalmers/University of Gothenburg, Göteborg, Sweden
Farbod Shokrieh, Cornell University, Ithaca, USA
Andreas Strömbergsson, Uppsala University, Uppsala Sweden
Anders Södergren, Chalmers/University of Gothenburg, Göteborg, Sweden
Sofia Tirabassi, University of Bergen, Bergen, Norway
Manh Hung Tran, Chalmers/University of Gothenburg, Göteborg, Sweden
Olivier Wittenberg, Ecole normale supérieure of Paris, Paris, France
We would like to thank the Institut Mittag-Leffler for hosting our conference. We had participants from many different places inside and outside of Europe. The meeting provided a forum for a series of high-level mathematical talks on varying topics: problems in geometric integration of differential equations, rough paths and regularity structures, optimal mass transport, and Kähler-Einstein geometry. In addition to excellent talks, we were glad to witness many lively discussions, particularly between mathematicians from completely different research fields. In fact, one of the main aims of the workshop was to bring together researchers with varying backgrounds – there were many researchers that met for the first time. Now, about six months after the workshop, we are happy to report that some of these encounters have resulted in new collaborations, for example between researchers in Kähler geometry and optimal transport, and a joint book project on “Pitfalls in infinite-dimensional geometry”.

**Algebraic and Geometric Aspects of Numerical Methods for Differential Equations**

**July 2–6, 2018**

**Organizers:** Elena Celledoni, NTNU – Norwegian University of Science and Technology; Kurusch Ebrahimi-Fard, NTNU – Norwegian University of Science and Technology; Klas Modin, Chalmers/University of Gothenburg; Brynjulf Owren, NTNU – Norwegian University of Science and Technology and Hans Z. Munthe-Kaas, University of Bergen
PARTICIPANTS

Ismael Bailleul, Université de Rennes 1, Rennes, France
Jean-David Benamou, Inria, Paris, France
Geir Bogfjellmo, ICMA T, Institute of Mathematical Sciences, Madrid, Spain
Yann Brenier, École Polytechnique, Palaiseau Cedex, France
Yvain Bruned, Imperial College London, London, United Kingdom
Elena Celledoni, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Charles Curry, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Kurusch Ebrahimi-Fard, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
François Gay-Balmaz, Ecole normale supérieure de Paris, Paris, France
Barbara Gris, KTH Royal Institute of Technology, Stockholm, Sweden
Ernst Hairer, University of Geneva, Geneva, Switzerland
Anders C. Hansen, University of Cambridge, Cambridge, United Kingdom
Evelyne Hubert, Inria Sophia Antipolis – Médiiterranée, Sophia Antipolis, France
Jakob Hultgren, Chalmers/University of Gothenburg, Göteborg, Sweden
Arieh Iserles, University of Cambridge, Cambridge, United Kingdom
Karolina Kropielnicka, University of Gdańsk, Gdańsk, Poland
Michael Lindsey, University of California, Berkeley, Berkeley, USA
Christian Lubich, Universität Tübingen, Tübingen, Germany
Dominique Manchon, Université Clermont Auvergne, Clermont-Ferrand, France

Elizabeth Mansfield, University of Kent, Kent, United Kingdom
Klas Modin, Chalmers/University of Gothenburg, Göteborg, Sweden
Brynjulf Owren, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Frédéric Patras, Université de Nice – Sophia Antipolis, Nice, France
Rosa Preiss, TU – Technische Universität Berlin, Berlin, Germany
Reinout Quispel, La Trobe University, Melbourne, Bundoora, Australia
Yanir Rubinstein, University of Maryland, College Park, USA
Jesus M. Sanz Serna, Universidad Carlos III de Madrid, Madrid, Spain
Alexander Schmeding, TU – Technische Universität Berlin, Berlin, Germany
Katharina Schratz, Karlsruhe Institute of Technology, Karlsruhe, Germany
Pranav Singh, University of Oxford, Oxford, United Kingdom
Ari Stern, Washington University in St. Louis, St. Louis, USA
Alice Barbara Tumpach, Université de Lille 1, Villeneuve d’Ascq, France
Olivier Verdier, University of Bergen, Bergen, Norway
Francois-Xavier Vialard, Université Paris-Dauphine, Paris, France
Danyu Yang, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Hans Z. Munthe-Kaas, University of Bergen, Bergen, Norway
Lorenzo Zambotti, Laboratoire de Probabilités, Statistique et Modélisation, Paris, France

Categorification and Higher Representation Theory

July 9–13, 2018
Organizers: Volodymyr Mazorchuk, Uppsala University; Aaron Lauda, The University of Southern California

SCIENTIFIC REPORT

The conference had 40 participants from all over the globe from Europe, Asia, Australia and both South and North America. In addition to these, several other colleagues from both Stockholm and Uppsala visited talks during the conference. The conference program consisted of 24 main talks, 45 minutes each, and of 8 poster presentations, 10 minutes each. These presentations described recent advances and developments in the following areas: categorification of mathematical structures appearing in algebra and topology, application of categorification techniques to the study of representations of algebraic
groups, Lie algebras and Lie superalgebras, application of categorification techniques to the study of invariants of various topological objects including knots, links and 3-manifolds, the abstract structure theory of bicategories, tensor categories and 2-categories, 2-representation theory of both abstract and concrete 2-categories, in particular, of the 2-category of Soergel bimodules.

The conference program also left ample time for discussions and collaboration between participants. This was very productive, and several groups of participants used this opportunity for work on their ongoing research projects. The informal sessions also allowed for junior researchers to foster new interactions and gain new insights on the different facets of this rapidly developing subject.

PARTICIPANTS
Anna Beliakova, University of Zurich, UZH, Zürich, Switzerland
Jon Brundan, University of Oregon, Eugene, USA
Chih-Whi Chen, Uppsala University, Uppsala, Sweden
Kevin Coulembier, The University of Sydney, Sydney, Australia
Michael Ehrig, The University of Sydney, Sydney, Australia
Brendan Frisk Dubsky, Uppsala University, Uppsala, Sweden
Thorsten Heidersdorf, Max Planck Institute for Mathematics, Bonn, Germany
Matthew Hogancamp, University of Southern California, Los Angeles, USA
Helena Jonsson, Uppsala University, Uppsala, Sweden
Mikhail Khovanov, Columbia University, New York, USA
Alexander Kleshchev, University of Oregon, Eugene, USA
Hankyoung Ko, University of Bonn, Bonn, Germany
Aaron Lauda, University of Southern California, Los Angeles, USA
Robert Laugwitz, Rutgers, The State University of New Jersey, New Brunswick, USA
Nicolas Libedinsky, Universidad de Chile, Santiago de Chile, Chile
Anthony Licata, Australian National University, Canberra, Australia
Marco Mackaay, University of Algarve, Faro, Portugal
Ruslan Maksimau, Université de Montpellier, Montpellier, France
Volodymyr Mazorchuk, Uppsala University, Uppsala, Sweden
Peter McNamara, The University of Queensland, Brisbane, Australia
Vanessa Miemietz, University of East Anglia, Norwich, United Kingdom
Grégoire Naisse, Université Catholique de Louvain, Louvain-la-Neuve, Belgium
Elin Persson Westin, Uppsala University, Uppsala, Sweden
Nonlocal Interactions in Partial Differential Equations and Geometry

May 21–25, 2018

Organizers: Luz Roncal, Basque Center for Applied Mathematics (BCAM) and Diana Stan, Basque Center for Applied Mathematics (BCAM)

SCIENTIFIC REPORT

The conference was the eighth edition of the European Women in Mathematics Summer School. The topics of the Summer School were embedded in the area of Elliptic Partial Differential Equations and they had a strong motivation from Geometrical Analysis.

The Summer School was chosen after a call opened by the European Women in Mathematics and the European Mathematical Society. It was mainly oriented to PhD and postdoc students that were interested in deepening into the above-mentioned topics, with special encouragement for the participation of women mathematicians.

The theory of second order elliptic equations has been flourishing during the last fifty years, and in the last decade has experienced some major advances. Deep mathematical concepts lead to the field of elliptic PDE’s, such as competitive systems, scattering theory or the Yamabe problem. The frameworks of study may be also diverse, ranging from the Euclidean setting to hyperbolic spaces. Moreover, there are important applications to population dynamics, theoretical physics or differential geometry. In Europe there is an important mathematical community working in the area of elliptic PDE’s, brilliant women mathematicians with strong influence in the development of the field. The main goal of this summer school was to introduce two research lines of current interest in Elliptic PDE’s: Competitive Interaction Systems and The Fractional Yamabe Problem. These topics were developed through corresponding series of lectures (5 hours each). The titles of the mini-courses and the lecturers were:

1. Geometric Aspects of Phase Separation, lectured by Prof. Susanna Terracini from the University of Torino, Italy.

2. The Fractional Yamabe Problem, lectured by Prof. Maria del Mar González from the University Autónoma of Madrid, Spain.

The lectures were complemented with 5 plenary talks given by experts in the field, 6 long talks (30 minutes
each) and short talks by PhD students and early career postdocs. A poster session was also organized. In this way, young researchers had the opportunity to be actively involved in the School.

PARTICIPANTS

Elisa Affili, University of Milan, Milano, Italy
Begoña Barrios, University of La Laguna, La Laguna, Spain
Judith Berendsen, Westfälische Wilhelms-Universität Münster, Münster, Germany
Cristina Brändle, Universidad Carlos III de Madrid, Madrid, Spain
Eleonora Cinti, University of Bologna, Bologna, Italy
Lucilla Corrias, Université d’Evry Val d’Essonne, Evry, France
Azahara de la Torre, University of Freiburg, Freiburg, Germany
María del Mar González, Universidad Autónoma de Madrid, Madrid, Spain
Felix del Teso, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Daniel Eceizabarrena, Basque Center for Applied Mathematics (BCAM), Bilbao, Spain
Jørgen Endal, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Maria Farcasceanu, University of Craiova, Craiova, Romania
Veronica Felli, University of Milano-Bicocca, Milano, Italy
Marco Fontelos, ICMAT, Institute of Mathematical Sciences, Madrid, Spain
Andreea Grecu, IMAR Institute of Mathematics “Simion Stoilow” of the Romanian Academy, Bucharest, Romania
Katrin Grunert, NTNU – Norwegian University of Science and Technology, Trondheim, Norway
Sangdon Jin, KAIST, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea
Milosz Krupski, University of Wroclaw, Wroclaw, Poland
Simon Larson, KTH Royal Institute of Technology, Stockholm, Sweden
Javier Martínez, Basque Center for Applied Mathematics (BCAM), Bilbao, Spain
Maria Medina, Pontificia Universidad Católica de Chile, Santiago, Chile
Monica Musso, University of Bath, Bath, United Kingdom
Roberto Ognibene, University of Milano-Bicocca, Milano, Italy
Luz Roncal, Basque Center for Applied Mathematics (BCAM), Bilbao, Spain
Andrea Serio, Stockholm University, Stockholm, Sweden
Nikita Simonov, Universidad Autónoma de Madrid, Madrid, Spain
Mariana Smit Vega García, University of Washington, Seattle, USA
Diana Stan, Basque Center for Applied Mathematics (BCAM), Bilbao, Spain
Denisa Stancu, Politehnica University of Bucharest, București, Romania
Susanna Terracini, University of Turin, Turin, Italy
Sundaram Thangavelu, Indian Institute of Science, Bangalore, India
Luis Vega, Basque Center for Applied Mathematics (BCAM), Bilbao, Spain
Havva Yoldas, Basque Center for Applied Mathematics (BCAM), Bilbao, Spain
Other Activities

Rolf Schock Prize Symposia

The institute hosted the 2018 Rolf Schock Prize Symposia in Mathematics and in Logics on October 17–18. The lectures at the Mathematics Symposium were held by:

- Ronald Coifman, Yale University, USA, Rolf Schock Prize laureate
- Guy David, Université Paris-Sud, France
- Roy R. Lederman, Yale University, USA
- Mauro Maggioni, Johns Hopkins University, USA
- Yves Meyer, École Normale Supérieure Paris-Saclay, France
- Jan-Olov Strömberg, KTH Royal Institute of Technology, Sweden
- Christophe Thiele, Hausdorff Center for Mathematics, Germany
- Peter W. Jones, Yale University, USA

Klein Days

The purpose of the Klein Days is to fill the knowledge and learning gap within mathematics between upper secondary school students in Sweden and the university level of mathematics giving insight into the respective mathematical approaches and teaching situations. Three times a year, 20 high school teachers of mathematics are invited to Institut Mittag-Leffler together with mathematics professors and university teachers. For three days, they inspire each other and develop tomorrow’s mathematics lessons for high school students, by combining the pedagogical expertise of high school teachers with the advanced subject knowledge of higher mathematics. The Klein Days is an appreciated learning and development opportunity aiming to create lessons in mathematics with an instant impact on high school students all around Sweden.

Organizers: Mats Boij, KTH Royal Institute of Technology, Stockholm
SCIENTIFIC REPORT

The teacher development program the Klein Days for high school teachers in mathematics has been arranged three times during 2018 by Svenska kommittén för matematikutbildning (SKM) together with Institut Mittag-Leffler and financed by Brummer & Partners. In June, the minister for upper secondary education, Anna Ekström visited the Klein Days. The program in August was specially directed towards previous participants and included two sessions of experience exchange in addition to the usual program with inspirational lectures by university professors followed by work in groups in order to develop lesson plans that can be implemented in high school classrooms. All three programs were well received by the participants.

JANUARY 12–14

Lecturers

Jana Madjarova, Chalmers/GU, Om att bevisa och motbevisa påståenden

Mats Boij, KTH Royal Institute of Technology, Invarianter

Stefan Karlsson, Skövde, Matematik och musik i harmoni

Tomas Ekholm, KTH Royal Institute of Technology, Monte Carlo och programmering

Lesson pilots

Mats Boij [KTH Royal Institute of Technology], Adem Limani [Lund], Tien Truong [Lund], Johannes Borgqvist [Chalmers/GU]

Participants

Gustav Bohlin, LM Engströms Gymnasium, Göteborg
Mats Boij, KTH Royal Institute of Technology, Stockholm
Johannes Borgqvist, Chalmers/University of Gothenburg, Göteborg
Ellenor Calla, Vuxenutbildningen i Örnsköldsvik, Örnsköldsvik
Tomas Ekholm, KTH Royal Institute of Technology, Stockholm
Roger Fermsjö, Södra Latins gymnasium, Stockholm
Marianne Forss, Jämtlands Gymnasium Wargentin, Östersund
Markus Fransson, Viktor Rydberg Gymnasium Odenplan, Stockholm
Gunnar Genell, Täby Enskilda Gymnasium, Täby
Fouzieh Hassankhali, Värmdö gymnasium, Stockholm
Jenny Homann, Hvitfeldska gymnasiet, Göteborg
Urban Hultström, Järfälla Gymnasium, Järfälla
Rickard Janveden, Fridaygymnasiet, Vänersborg
Bengt Johnsson, Falkenbergs gymnasieskola, Falkenberg
Stefan Karlsson, University of Skövde, Skövde
Adem Limani, Lund University, Lund
Jennifer Litteral-Johansson, Hjalmar Strömerskolan, Strömsund
Jana Madjarova, Chalmers/University of Gothenburg, Göteborg
Jesper Nelsén, Danderyds gymnasium, Danderyd
Sandra Näslund, Vuxenutbildningen i Örnsköldsvik, Örnsköldsvik
Malin Skårner, Viktor Rydberg Gymnasium Odenplan, Stockholm
Mirela Tar, Viskastrandsgymnasiet, Borås
Tien Truong, Lund University, Lund
Sten Weman, Vadsbogymnasiet, Mariestad

**JUNE 7–9**

**Lecturers**

Knut Marken, Oslo, *Noen refleksjoner rundt hvordan programmering kan bidra til fornyelse av matematikkutdanningen*

Niklas Eriksen, Örebro, *Partitioner av heltal*

Irina Pettersson, Gävle, *Asymptotisk analys genom exempel*

Tobias Ekholm, IML and Uppsala, *Knutar och länkar*

**Lesson pilots**

Oliver Krüger (Stockholms universitet), Karl Jonsson (KTH Royal Institute of Technology), Mats Boij (KTH Royal Institute of Technology), Dan Lilja (Uppsala universitet)

**Participants**

Mats Boij, KTH Royal Institute of Technology, Stockholm
Kristin Bratsberg, Djurgymnasiet Stockholm, Stockholm
Gunilla Edman, Gymnasieskolans Spyken, Lund
Tobias Ekholm, IML and Uppsala University, Uppsala
Anders Enbom, Danderyds gymnasium, Danderyd
Slavica Enving, S:t Petri skola, Malmö
Niklas Eriksen, Örebro University, Örebro
Michael Hutt, Rinmangymnasiet, Eskilstuna
Claes Johansson, Luleå gymnasieskola, Luleå
Karl Jonsson, KTH Royal Institute of Technology, Stockholm
Thomas Karlsson, Sven Eriksson Gymnasiet, Borås
Oliver Krüger, Stockholm University, Stockholm
Lars-Erik Larsson, Drottning Blankas gymnasium Falun, Falun
Dan Lilja, Uppsala University, Uppsala
Niklas Lindberg, Viktor Rydberg Gymnasium Odenplan, Stockholm
Knut Marken, University of Oslo, Oslo
David Nordqvist, De la Gardiesgymnasiet Norra, Lidköping
Malin Otter Fröjd, Sandbackaskolan, Arvika
Irina Pettersson, University of Gävle, Gävle
Monika Preisner, Burgårdens utbildningscentrum, Göteborg
Anita Ristamäki, Jämtlands Gymnasium Wargentin, Östersund
Ann-Therése Simonsson, Nösnäs gymnasiet, Stenungsund
Lisa Sjölund, Malgomajskolan, Vilhelmina
Erik Skäringer, Birgittaskolan, Linköping
Ann-Sofie Sköldberg, Rinmangymnasiet, Eskilstuna
Julia Tsygan, The International School of the Stockholm region [ISSR], Stockholm
Magnus Widström, AlmaAkademien, Karlstad
Mikael Zeidlitz, Ridskolan Strömsholm, Strömsholm

AUGUST 17–19
Lecturers
Axel Hultman, Linköping, Femfärgssatsen
Mats Boij, KTH Royal Institute of Technology, Problem
Roy Skjelnes, KTH Royal Institute of Technology, Hur långt är det med flyg?
Sara Zahedi, KTH Royal Institute of Technology, Numeriska metoder för differentialekvationer

Lesson pilots
Mats Boij [KTH Royal Institute of Technology], Lea Versbach [Lund], Joar Bagge [KTH Royal Institute of Technology]

Participants
Joar Bagge, KTH Royal Institute of Technology, Stockholm
Mats Boij, KTH Royal Institute of Technology, Stockholm
Magnus Dahlström, Pauliskolan, Malmö
Camilla Engberg, Sundsvalls Gymnasium Hedbergska, Sundsvall
Roger Fermsjö, Södra Latins gymnasium, Stockholm
Anders Floren, Enskilda Gymnasium, Stockholm
Ana Fuentes Martinez, Katedralskolan Lund, Lund
Gunnar Genell, Täby Enskilda Gymnasium, Täby
Michael Gurebo, Göteborgs högre samskola, Göteborg
Susanne Hellström, Leksands Gymnasium, Leksand
Axel Hultman, Linköping University, Linköping
Vera Lundström, Dragonskolan, Umeå
Berthold Nilsson, Hultsfreds gymnasium, Hultsfred
Teresa Opacic, St Eskils gymnasium, Eskilstuna
Nikke Palmberg, Vasa Övningsskola, Vasa
Therese Rodger, Osbecksgymnasiet, Laholm
John Rödin, Östra gymnasiet, Trängsund
Per-Olof Sjöberg, Jämtlands Gymnasium Wargentin, Östersund
Roy Skjelnes, KTH Royal Institute of Technology, Stockholm
Anna Stenkvist, Norra Real, Stockholm
Måns Svensson, LBS – kreativa gymnasiet, Göteborg
Anna Svärd Olsson, Erehrensvarska Gymnasiet, Karlskrona
Lea Versbach, Lund University, Lund
Sara Zahedi, KTH Royal Institute of Technology, Stockholm

The participants of the Klein Days in August, 2018.
Mobility Program

Departments of mathematics at several Swedish universities participate in a mobility program inviting IML program participants. A researcher from the current program gives a talk at one of the participating institutions. The institute also welcomes researchers and post-docs at the departments to participate in program activities.

Library and Historical Archive

The library is every year trying to adapt to the new world of publishing, distribution and open access, in order to increase access and reduce subscription costs.

There is a continuous interest in documents from the archives at Institut Mittag-Leffler relating to Gösta Mittag-Leffler, Sofia Kovalevskaya, Karl Weierstrass, and Henri Poincaré, as well as many others connected to Mittag-Leffler through the preserved correspondence. One example is the forthcoming publication of the correspondence between the Italian mathematician Vito Volterra and Mittag-Leffler. Mathematicians, science historians, authors, publishers, and others regularly request information from the historical archive.

Several of our collections of older books and documents have now been transferred to the new large, climate-controlled archive. This will continue during 2019.

Public Awareness

The increasing public awareness of the importance of Gösta Mittag-Leffler resulted in a record of number of guided tours of the institute in 2018. Displays of volumes from the rare book collection are popular and inspiring moments for our participants, and a regular event during the Klein Days each year.
## Financial Overview

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