9th BMS Student Conference

March 03-05, 2021

Online Conference

Berlin Mathematical School

BMS

https://bmsstudconf.github.io/2021/

Welcome!

It is our pleasure to welcome you to the 9th BMS Student Conference! The main novelty compared to past editions is the online format for the first time ever due to the COVID-19 pandemic. It is our aspiration that this brand new style keeps the community spirit of previous editions.

The conference is organized by students for students, aiming to connect current and prospective students of mathematics (and related disciplines) in Berlin. Its main goals are to help current students learn about each other's interests and to help prospective students to get to know better Berlin's mathematical landscape as well as the social environment at the BMS.

In this booklet, you can find information about the conference, including a schedule of events, list of abstracts, and a description of the online platforms that will be used. Most of the information is also available on the conference webpage.

We would like to thank Professor Carla Cederbaum and Professor Barbara Zwicknagl for accepting our invitations, the student speakers for contributing to our conference, and all participants for joining us at this event. We are also grateful to the BMS for supporting this initiative and to all of our fellow students who helped with the organization.

If you have any questions or concerns, please do not hesitate to contact us. We wish you a great time at our conference!

Organizers:

Ángel Crespo Blanco	(TU Berlin)
Shah Faisal	(HU Berlin)
Florian Nie	(TU Berlin)
Yoanna Kirilova	(HU Berlin)
Colin Rothgang	(TU Berlin)
Krizstina Siladji	(Utrecht University)

Website:

https://bmsstudconf.github.io/2021/

E-Mail:

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Schedule

	Wednesday	Thursday	Friday
09 : 50 – 10 : 00	**Welcome**		
10 : 00 – 10 : 25	Faisal	Manikandan	Rehberg
10 : 30 – 10 : 55	Đukić	Sadiku	Merino
11 : 00 – 11 : 25	**Coffee Break**	**Coffee Break**	**Coffee Break**
11 : 30 – 11 : 55			
12 : 00 – 12 : 25	Prof. Cederbaum	Prof. Zwicknagl	Šobot
12 : 30 – 12 : 55	(Invited Speaker)	(Invited Speaker)	Güdücü
13 : 00 – 13 : 25	**Lunch**	**Lunch**	**Lunch**
13 : 30 – 13 : 55			
14 : 00 – 14 : 25			
14 : 30 – 14 : 55	Flatt	Tornquist	Wessels
15 : 00 – 15 : 25	Flores	Shevchenko	**Closing**
15 : 30 – 15 : 55	**Coffee Break**	**Coffee Break**	
16 : 00 – 16 : 25			
16 : 30 – 16 : 55	Ghani Varzaneh	Morris	
17 : 00 – 17 : 30	Hager	Yuan	
18 : 30–		**Social event**	

Online platforms

The conference will take place in an online format based on the following platforms.

Zoom

Zoom is the video call platform that will be used to broadcast the talks. Details of the rooms and meetings will be communicated by email to all registered participants.

Make sure you have it installed on your device and check for updates a few days before the conference. The reason for this is that each meeting launched from an account linked to the license of some of the Berlin universities usually requires one of the latest versions to work (for security reasons mainly).

The talks will be recorded, and then uploaded and made public or not according to each speaker's wishes. Due to the nature of the recording, people from the audience might be present in the image or audio, for example in the questions round. If someone does not want to appear in it, it is recommended to hide your image, audio and name. We will remember this at the moment.

Wonder Me

Wonder Me is the social interaction platform that will be used for socializing and networking in the breaks. Each registered participant will receive the links via email to join the rooms of the conference.

In this platform each participant controls a small character in a 2-D style world, and when approaching one of the other characters both of you start a spontaneous overlaid video call between you (together with the other people who are also close).

We encourage everyone to join us in Wonder Me at any coffee break and also at the lunch break. We think that this could give the closest experience to the spontaneous gatherings and conversations that usually happen in a conference.

Social Event

Online games and chill out session - Thursday 18:30

On Thursday after the last talks you are all welcome to one more social gathering. Details of the platform will be communicated via email to the registered participants. It will be possible to spontaneously split in small groups according to the interests of each one of you, much like in live events, and within these groups one could simply have conversations with the rest of the participants; play some online games that we will propose (and any attendant can propose at the moment too); or anything that comes to mind. Please come, join us and meet the other participants in a different context.

Invited Speakers

Carla Cederbaum

Carla Cederbaum is a professor of Mathematics at the University of Tübingen. She has received her doctorate in 2011 from the Free University (FU) of Berlin under the supervision of Gerhard Huisken. Besides mathematical research, she is involved in communicating mathematics to general public too.

Carla's research interests are Mathematical Relativity, Differential Geometry, Geometric Analysis.

For more information, visit her webpage.

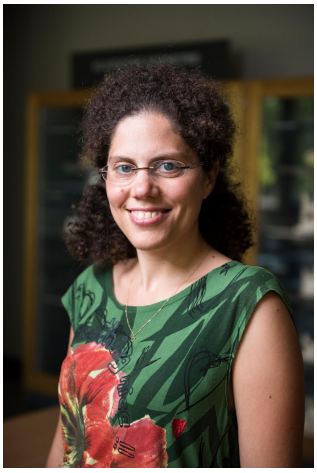


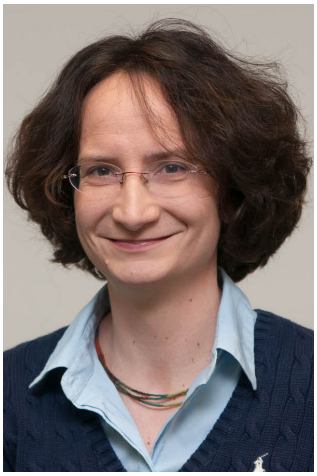
Photo by: Christoph Jäckle / Universität Tübingen

Barbara Zwicknagl

Barbara Zwicknagl received PhD in applied Mathematics from the Hausdorff Institute for Mathematics in Bonn under the supervision of Stefan Müller in 2011. She has worked as a researcher in many different institutions before joining the applied Mathematics research group at Humboldt University (HU). Currently, she is working as professor and chair of the applied mathematics search group at HU, Berlin. She also gives her services as an Executive Board and Council member of MATH+.

Her research focuses on variational calculus, approximation theory and non-linear elasticity.

More information can be found on her webpage.



Websites for the invited speakers can also be found at the conference web page (see the cover).

Abstracts - Invited speakers

Wednesday 12:00, 03/03/2021

On CMC-foliations of asymptotically Euclidean manifolds

Carla Cederbaum (University of Tübingen)

Three-dimensional Riemannian manifolds are called asymptotically Euclidean if, outside a compact set, they are diffeomorphic to the exterior region of a ball in Euclidean space, and if the Riemannian metric converges to the Euclidean metric as the Euclidean radial coordinate r tends to infinity. In 1996, Huisken and Yau proved existence of a foliation by constant mean curvature (CMC) surfaces in the asymptotic end of an asymptotically Euclidean Riemannian three-manifold. Their work has inspired the study of various other foliations in asymptotic ends, most notably the foliations by constrained Willmore surfaces (Lamm—Metzger—Schulze) and by constant expansion/null mean curvature surfaces in the context of asymptotically Euclidean initial data sets in General Relativity (Metzger, Nerz).

After a rather extensive introduction of the central concepts and ideas, I will present a new foliation by constant spacetime mean curvature surfaces (STCMC), also in the context of asymptotically Euclidean initial data sets in General Relativity (joint work with Sakovich). This STCMC-foliation is well-suited to define the center of mass of an isolated system in General Relativity and thereby answers some previously open questions of relevance in General Relativity. Previous knowledge of General Relativity and Riemannian Geometry will not be assumed.

Thursday 12:00, 04/03/2021

A variational view on pattern formation in helimagnets

Barbara Zwicknagl (HU Berlin)

Pattern formation in materials can often be explained in the context of the calculus of variations. The resulting minimization problems are often analytically and numerically challenging due to their nonlocal and/or nonconvex structure. In many cases, explicit minimizers cannot be computed explicitly. As a first step towards the understanding of low-energy states and qualitative properties of minimizers (such as periodicity or self-similarity) one often focuses on the scaling of the minimal energy in terms of the problem parameters. This requires the explicit construction of good competitors and the proof of a matching ansatz-free lower bound.

In this talk, I will illustrate some of the techniques in the context of a model for helimagnets.

This talk is partly based on joint work with Janusz Ginster.

Abstracts - Student Contributed talks

Wednesday, 03/03/2021

10:00 J-holomorphic curves are very great

Shah Faisal (HU Berlin)

J-holomorphic curves are very powerful in studying the topology of symplectic manifolds. The existence of certain J-holomorphic curves in a symplectic manifold obstruct symplectic embeddings into the underlying symplectic manifold. In fact, there is this Eliashberg's Principle that says that any obstruction to a symplectic embedding (beyond the volume condition) can be described by a J-holomorphic curve. In this talk, we give an example of this phenomenon, namely, the non-squeezing theorem of Gromov. We will demonstrate how the presence of a J-holomorphic sphere forbids the symplectic embedding of some Euclidean balls into some symplectic manifolds.

10:30 Leaf-wise intersections for coisotropic submanifolds

Milica Đukić (HU Berlin)

Arnold's question about fixed points of Hamiltonian diffeomorphisms and Lagrangian intersections led to Moser's study of coisotropic leaf-wise intersections. The result showed that leaf-wise intersections exist for Hamiltonian diffeomorphisms C^1-close to identity. Ekeland, Hofer proved a generalization of this result for contact-type hypersurfaces and Hamiltonian diffeomorphisms with energy bounded by certain symplectic capacity, turning this into a question of displacement energy. We will explain results of a variational approach for contact coisotropic submanifolds using generalized perturbed Rabinowitz action functional introduced by Albers, Frauenfelder, Kang.

14:30 Extensions of Toric Line Bundles

Amelie Flatt (FU Berlin)

Toric geometry allows us to translate algebro-geometric problems to questions in discrete geometry, in particular the geometry of lattice polyhedra. This provides accessible tools for computing interesting invariants of toric varieties. For instance, the cohomology of sheaves associated to divisors on toric varieties can be calculated from the singular cohomology of certain discretely defined sets. One method of calculating this has been know for several decades, another description was given by Klaus Altmann and others in two papers in 2018 and 2019.

In my master's thesis, I used this new description of the sheaf cohomology of divisors to give a discrete-geometric interpretation of the first extension group $Ext^1(\mathcal{L}^-, \mathcal{L}^+)$ of two line bundles $\mathcal{L}^-$ and $\mathcal{L}^+$ on a toric variety. I showed how an inclusion/exclusion sequence of lattice polyhedra gives rise to a universal extension sequence for $Ext^1(\mathcal{L}^-, \mathcal{L}^+)$.

In this talk I will give a brief introduction to toric geometry and show how discrete geometry comes into play. I will show examples of how invariants of toric varieties can be calculated from discrete-geometric data. Finally, I will sketch the result of my master's thesis connecting a "polyhedral extension sequence" to the algebro-geometric $Ext^1(\mathcal{L}^-, \mathcal{L}^+)$. .

15:00 Bruinier and Raum's theorem, but cohomological and arithmetic

Marco Flores (HU Berlin)

Siegel modular forms are higher dimensional analogues of classical modular forms: while the latter are sections of a line bundle in the moduli of elliptic curves, the former are such in the moduli of principally polarized abelian varieties. A phenomenon that appears with this generalization is the Fourier-Jacobi series of a Siegel modular form. One might wonder if any formal series of that shape comes from a Siegel modular form. Bruinier and Raum answered the question affirmatively, over the complex numbers, in 2014.

In this talk we study the problem over the integers, and we reformulate it in a way that will lead us to investigate the cohomology of certain sheaves in toric varieties.

16:30 Semi-invertible Multiplicative Ergodic Theorem (MET) on the fields of Banach spaces

Mazyar Ghani Varzaneh (TU Berlin)

The Multiplicative Ergodic Theorem (MET) is a powerful tool with various applications in different fields of mathematics, including analysis, probability theory, and geometry, and a cornerstone in smooth ergodic theory. It was first proved by Oseledets for matrix cocycles, since then, the theorem attracted many researchers to provide new proofs and formulations with increasing generality.

In this talk motivated by our models in stochastic delay equations and stochastic partial differential equations (SPDE), we will present a version of MET for stationary compositions on a (possibly random) field of (potentially

distinct) Banach spaces, depending on the random sample. (Joint work with Sebastian Riedel).

17:00 Optimal Stopping with signatures

Paul Hager (TU Berlin)

We propose a new method for solving optimal stopping problems (such as American option pricing in finance) under minimal assumptions on the underlying stochastic process X. We consider classic and randomized stopping times represented by linear functionals of the rough path *signature* $\mathbb{X}^{<\infty}$ associated to X, and prove that maximizing over the class of *signature stopping times*, in fact, solves the original optimal stopping problem. Using the algebraic properties of the signature, we can then recast the problem as a deterministic optimization problem depending only on the truncated expected signature $E[X \leq N]$. The only assumption on the process X is that it admits a lift to a continuous (geometric) random rough path. Hence, the theory encompasses processes such as fractional Brownian motion which fail to be either semi-martingales or Markov processes.

Thursday, 04/04/2021

10:00 Riemann Surfaces and Projective curves, are they same?

Naageswaran Manikandan (HU Berlin)

Algebraic geometry studies algebraic varieties which are locally defined by polynomials and Analytic geometry deals with complex manifolds or more generally analytic manifolds which are locally defined by holomorphic functions. During 1950s and 1960s, Jean Pierre Serre and Alexander Grothendieck laid the foundational work for the modern algebraic geometry. Two major papers by Serre were Faisceaux Algébriques Cohérents (FAC, 1955) and Géometrie Algébrique et Géométrie Analytique (GAGA, 1956). The latter describes a beautiful and deep underlying connection between algebraic and analytic geometry.

In this talk, I will give a brief overview of this connection using Riemann surfaces as the prime example.

10:30 Neural Network Approximation Theory

Shpresim Sadiku (TU Berlin and ZIB)

We review classical and modern results in approximation theory of neural networks. First, the density of neural networks within different function spaces under various assumptions on the activation function is considered. Next, lower and upper bounds on the order of approximation with neural networks are given based on the input dimension, the number of neurons and a parameter quantifying the smoothness of the target function. Lastly, a family of compositional target functions for which the curse of dimensionality can be overcome using deep neural networks is examined.

14:30 Analysis of dynamic phase-field fracture

Sven Tornquist (HU Berlin and WIAS Berlin)

A model for the description of dynamic crack growth in (visco-)elastic materials will be introduced. Using a phase-field approach where the sharp crack interface is regularized with a volumetric approximation, certain challenges regarding the analysis of the model are discussed and an application oriented solution strategy is presented.

15:00 Connection between integrability of a multi-valued function and its convex hull

Olha Shevchenko (National University of Kharkiv, Ukraine)

For a Banach space X a multi-function with values in X is a map $f : [0, 1] \to 2^X \setminus \{\emptyset\}$. Using Minkowski addition and convergence in the sense of Hausdorff distance, one can define Riemann integral of a multi-function similarly to that of a real-valued function.

The convex hull of a multi-function F is the multi-function $convF : t \to conv(F(t))$. It is known that the convex hull of an integrable multi-function is also integrable. The inverse is known for Hilbert spaces. That is, every multi-function (with values in a Hilbert space) with an integrable convex hull is itself integrable. However, it is an open question for what Banach spaces the same result holds true. We present a complete solution for this open problem.

This is a joint work with Vladimir Kadets and Artur Kulikov.

The research was supported by the National Research Foundation of Ukraine funded by Ukrainian State budget as part of the project 2020.02/0096 "Operators in infinite-dimensional spaces: the interplay between geometry, algebra and topology".

16:30 Triangle factors in pseudorandom graphs

Patrick Morris (FU Berlin)

The study of random graphs is a central topic that lies at the intersection of Probability Theory and Combinatorics. In the past couple of decades, there has been great interest in so-called 'pseudorandom' graphs: graphs which resemble purely random graphs. This study is motivated by applications in Computer Science where true randomness is hard to come by. In this talk we will introduce the concept of pseudorandom graphs and discuss the problem of determining when a pseudorandom graph contains a certain subgraph. We will focus on one of the few cases where we actually have a satisfactory answer to this question; a recent breakthrough giving a tight condition on the level of pseudorandomness which guarantees the existence of a triangle factor in a graph.

17:00 Topological characterisations of Löwner traces

Yizheng Yuan (TU Berlin)

Löwner chains provide a way to encode certain planar domains and curves by real-valued "driving" functions. Originally a purely complex analytic tool to study conformal maps, it has turned out to be very useful in constructing SLE, a "uniformly random" curve in a domain. Not any curve can be described as a Löwner chain, but the ones that can (we call them traces) may

look very wild and even be space-filling. Intuitively, traces are characterised by the property that whenever they self-intersect, they need to "bounce off" instead of "crossing over".

In this talk, I will introduce Löwner chains and present three equivalent ways of describing the property that characterise traces.

Friday, 05/03/2021

10:00 Combinatorial reciprocity theorems for generalized permutahedra, hypergraphs, and pruned inside-out polytopes

Sophie Rehberg (FU Berlin)

Generalized permutahedra are a class of polytopes with many interesting combinatorial subclasses. We introduce pruned inside-out polytopes, a generalization of concepts introduced by Beck–Zaslavsky (2006),which have many applications such as recovering the famous reciprocity result for graph colorings by Stanley. We study the integer point count of pruned inside-out polytopes by applying classical Ehrhart polynomials and Ehrhart–Macdonald reciprocity. This yields a geometric perspective on and a generalization of a combinatorial reciprocity theorem for generalized permutahedra by Aguiar – Ardila (2017) and Billera–Jia–Reiner (2009). Applying this reciprocity theorem to hypergraphic polytopes allows us to give an arguably simpler proof of a recent combinatorial reciprocity theorem for hypergraph colorings by Aval–Karaboghossian–Tanasa (2020). Our proof relies, aside from the reciprocity for generalized permutahedra, only on elementary geometric and combinatorial properties of hypergraphs and their associated polytopes.

10:30 Symmetric Hamilton cycles on symmetric graphs

Arturo Merino (TU Berlin)

A cycle in a graph is said to be Hamilton if it spans all the vertices of the graph. Similarly, a graph will be Hamiltonian if it contains a Hamilton cycle. In 1969, Lovász conjectured that the symmetry of a graph heavily influences its Hamiltonicity. This idea gave birth to Lovász conjecture: Every connected symmetric graph is Hamiltonian except for five known counterexamples. There is vast literature showing that Lovász conjecture holds for natural classes of graphs; e.g. Hypercubes, Permutahedra, dense Kneser Graphs, etc. Very recently, Lovász conjecture was shown to hold for the middle levels graph; which is a particularly nice symmetric subgraph of the Hypercube. The known constructions of Hamilton cycles in the middle levels are not particularly symmetric, not giving clues towards the conjectured relation between symmetry and Hamiltonicity. Hence, in 2011 Knuth conjectured the existence of a Hamilton cycle which respects the natural symmetry of the middle levels (i.e. that is automorphism invariant).

12:00 Sum of two squares

Branislav Šobot (HU Berlin)

In this short talk we will discuss a very famous Fermat's theorem on sum of two squares which states that a prime number can be written as a sum of two squares iff it is not of the form $4k + 3$. This theorem, although very elementary, has several different proofs and perspectives which can be used as introductions to major areas of number theory such as algebraic number theory, analytic number theory, theory of Diophantine approximations etc. We will let the audience choose in which direction this talk will flow.

12:30 Classification port-Hamiltonian Differential Algebraic Equations

Candan Güdücü (TU Berlin)

The modeling framework of port-Hamiltonian (pH) systems is a universal model class, associated with a Dirac structure that encloses its energy balance properties. In this talk, pH systems will be introduced, then the possible structures of pH differential-algebraic equations (DAE) and the linear systems associated with them will be discussed. Lastly, we talk about solution of the associated linear systems which have a positive (semi-)definite symmetric part that can be exploited in the numerical solution. Lanczos-like methods for the solution of linear systems coming from pHDAEs are presented.

14:30 Stochastic Optimal Control in Infinite Dimensions

Lukas Wessels (TU Berlin)

First, we give an introduction to (stochastic) optimal control in finite dimensions and present the two classical approaches to optimal control problems: The dynamic programming approach and Pontryagin's maximum principle. In the second part of the talk, we focus on the optimal control of semilinear stochastic partial differential equations and emphasize the challenges in current research on stochastic optimal control in infinite dimensions.

List of Student Speakers

(Alphabetical by last name)

- Milica Đukić – Wednesday 10:30 – Leaf-wise intersections for coisotropic submanifolds
- Shah Faisal – Wednesday 10:00 – J-holomorphic curves are very great
- Amelie Flatt – Wednesday 14:30 – Extensions of Toric Line Bundles
- Marco Flores – Wednesday 15:00 – Bruinier and Raum's theorem, but cohomological and arithmetic
- Mazyar Ghani Varzaneh – Wednesday 16:30 – Semi-invertible Multiplicative Ergodic Theorem (MET) on the fields of Banach spaces
- Candan Güdücü – Friday 12:30 – Classification port-Hamiltonian Differential Algebraic Equations
- Paul Hager – Wednesday 17:00 – Optimal Stopping with signatures
- Naageswaran Manikandan – Thursday 10:00 – Riemann Surfaces and Projective curves, are they same?
- Arturo Merino – Friday 10:30 – Symmetric Hamilton cycles on symmetric graphs
- Patrick Morris – Thursday 16:30 – Triangle factors in pseudorandom graphs
- Sophie Rehberg – Friday 10:00 – Combinatorial reciprocity theorems for generalized permutahedra, hypergraphs, and pruned inside-out polytopes
- Shpresim Sadiku – Thursday 10:30 – Neural Network Approximation Theory
- Olha Shevchenko – Thursday 15:00 – Connection between integrability of a multi-valued function and its convex hull
- Branislav Šobot – Friday 12:00 – Sum of two squares
- Sven Tornquist – Thursday 14:30 – Analysis of dynamic phase-field fracture

- Lukas Wessels – Friday 14:30 – Stochastic Optimal Control in Infinite Dimensions
- Yizheng Yuan – Thursday 17:00 – Topological characterisations of Löwner traces