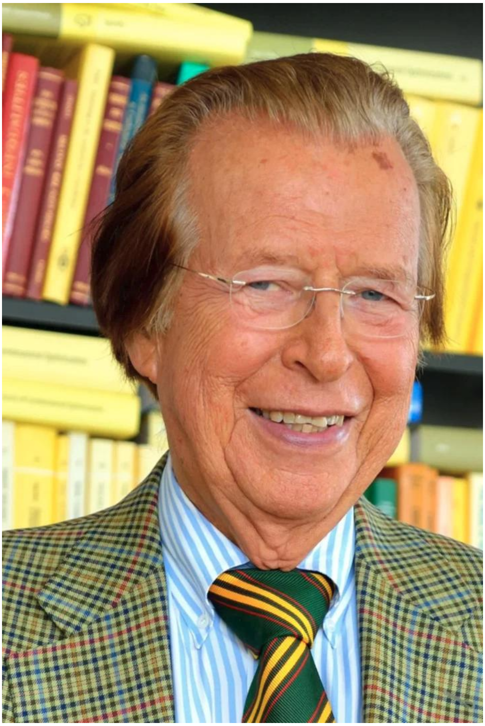
Bonn Workshop on Combinatorial Optimization

November 3–7, 2025



– commemorating Bernhard Korte –

organized by: William Cook, Michel Goemans, László Lovász, Jens Vygen

HAUSDORFF CENTER FOR MATHEMATICS

UNIVERSITÄT BONN

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  University of Bonn and Max Planck Institute for Informatics, Saarbrücken
- David Applegate
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- Jens Vygen
  University of Bonn
- Stefan Weltge
  Technical University of Munich

- David Williamson
  Cornell University
- Laurence Wolsey
  Université catholique de Louvain
- Rico Zenklusen
  ETH Zürich
- Guochuan Zhang
  Zhejiang University

This workshop is generously supported by the Hausdorff Center for Mathematics (HCM). This cluster of excellence exists since 2006 and has recently been renewed for the next seven years. The Research Institute for Discrete Mathematics is one of the six institutes of HCM. More information on https://www.mathematics.uni-bonn.de/hcm.

Wifi

SSID: dm-guest
Password: 1938korte2025

Library

Feel free to explore our library on the first floor, reachable from the stairwell. It contains one of the largest collections of literature on discrete mathematics and additionally offers some workplaces. It is open from 9:00 to 17:00.

Program

Monday

13:30–14:00	*Registration*
14:00–14:30	**Opening**
	– Session Chair: William Cook –
14:30–15:00	**Stephan Held** 38 years of mathematical innovations in chip design
15:00–15:30	**Jannis Blauth** Toward optimal approximations for resource-minimization for fire containment on trees and non-uniform k-center
15:30–16:00	**Laura Vargas Koch** Approximating Graphic Multi-Path TSP and Graphic Ordered TSP
16:00–16:30	*Coffee Break*
	– Session Chair: Laurence Wolsey –
16:30–17:00	**David Williamson** The 4/3 conjecture for the traveling salesman problem: a status update
17:00–17:30	**Sophia Heimann** A near-complete resolution of the exponential-time complexity of k-opt for the traveling salesman problem
17:30–18:00	**Luise Puhlmann** Approximating Asymmetric A Priori TSP beyond the adaptivity gap
18:00–20:00	*Welcome Reception*

Tuesday

	– Session Chair: Robert Bixby –
09:00–09:30	**Santosh Vempala** The complexity of convex optimization with membership oracles
09:30–10:00	**Bento Natura** Linear interior-point methods
10:00–10:30	**Haoyuan Ma** Optimal path following in the ℓ_2-neighbourhood
10:30–11:00	*Coffee Break*
	– Session Chair: Satoru Fujishige –
11:00–11:30	**Bruce Shepherd** Greedy algorithms for downwards closed set systems and polytopes
11:30–12:00	**Zoltán Szigeti** Augmenting a hypergraph to have a matroid-based (f, g)-bounded (α, β)-limited packing of rooted hypertrees
12:00–12:30	**Hannaneh Akrami** Matroids are equitable
12:30–14:30	*Lunch break (on your own)*
	– Session Chair: Martin Skutella –
14:30–15:00	**Dieter Rautenbach** A faster algorithm for independent cut
15:00–15:30	**Alexandra Lassota** A convoluted situation: fine-grained algorithms and complexity through the lens of min-plus convolution
15:30–16:00	**László Végh** From incremental transitive cover to strongly polynomial maximum flow
16:00–16:30	*Coffee Break*
	– Session Chair: Michael Jünger –
16:30–17:00	**András Sebő** Odd paths, cycles and cuts: connections and frontiers
17:00–17:30	**Siyue Liu** Approximately packing dijoins via nowhere-zero flows
17:30–18:00	**Niklas Schlomberg** Packing cycles in planar and bounded-genus graphs

Wednesday

10:00–12:00	**Commemoration Session**
12:00–14:00	*Lunch Reception*
	– Session Chair: Britta Peis –
14:30–15:00	**Lisa Sauermann** Asymptotically-tight packing and covering with transversal bases in Rota's basis conjecture
15:00–15:30	**Kristóf Bérczi** Interaction between skew-representability, tensor products, extension properties, and rank inequalities
15:30–16:00	**András Recski** Graphicness-preserving strong maps of matroids
16:00–16:30	*Coffee Break*
	– Session Chair: András Frank –
16:30–17:00	**Chandra Chekuri** Buy-At-Bulk and hop-constrained network design
17:00–17:30	**Meike Neuwohner** Approximation schemes for planar graph connectivity problems
17:30–18:00	**Chaitanya Swamy** Almost tight additive guarantees for k-edge connectivity
18:05–19:05	*Arithmeum tours*

Thursday

– Session Chair: Jaroslav Nešetřil –	
09:00–09:30	**Vera Traub** Unsplittable cost flows from unweighted error-bounded variants
09:30–10:00	**Daniel Ebert** Nucleolus, happy nucleolus, and vehicle routing
10:00–10:30	**Linda Cook** 200,000 colors suffice... for t-perfect graphs
10:30–11:00	*Coffee Break*
– Session Chair: Kazuo Murota –	
11:00–11:30	**Matthias Mnich** Fast approximation schemes for related machine scheduling
11:30–12:00	**Sharat Ibrahimpur** Stochastic load balancing with machine reservations
12:00–12:30	**Daniel Blankenburg** An efficient algorithm for minimizing ordered norms in fractional load balancing
12:30–14:30	*Lunch break (on your own)*
13:15–14:15	*Arithmeum tours*
– Session Chair: Samuel Fiorini –	
14:30–15:00	**Ravindran Kannan** Random projections and distance between polytopes
15:00–15:30	**Peter Gritzmann** Anisotrotic diagrams, and the representation of polycrystals
15:30–16:00	**Sándor Fekete** Hard in theory, easy in practice? Solving hard optimization problems in geometry and elsewhere
16:00–16:30	*Coffee Break*
– Session Chair: Giovanni Rinaldi –	
16:30–17:00	**Monique Laurent** Semidefinite approximations for bicliques and biindependent pairs
17:00–17:30	**Michel Goemans** Revisiting the integrality ratio for ATSP
17:30–18:00	**Jan Karel Lenstra** A historical note on the complexity of scheduling problems
18:05–19:05	*Arithmeum tours*
19:30–22:00	*Conference Dinner (at Tuscolo Münsterblick)*

Friday

– Session Chair: Karen Aardal –	
09:00–09:30	**R. Ravi** Two matching vignettes
09:30–10:00	**Stefan Weltge** Multiplicative assignment with upgrades
10:00–10:30	**Stefan Hougardy** Fast algorithms for Euclidean perfect matching
10:30–11:00	*Coffee Break*
– Session Chair: Alexander Schrijver –	
11:00–11:30	**Gérard Cornuéjols** The replication conjecture
11:30–12:00	**Ahmad Abdi** Lower bounds for cube-ideal set-systems
12:00–12:30	**László Lovász** Graph limits, matroid limits, and greedoids
12:30	**Closing**

Abstracts

Ahmad Abdi

Lower bounds for cube-ideal set-systems

A set-system $S \subseteq \{0,1\}^n$ is *cube-ideal* if its convex hull can be described by capacity and generalized set covering inequalities. In this work, we use combinatorics, convex geometry, and polyhedral theory to give exponential lower bounds on the size of cube-ideal set-systems, and linear lower bounds on their VC dimension. We then provide applications to graph theory and combinatorial optimization, specifically to strong orientations, perfect matchings, dijoins, and ideal clutters.

Based on joint work with Gerard Cornuejols, Daniel Dadush, and Mahsa Dalirrooyfard. The paper can be found on the arXiv at https://arxiv.org/abs/2505.14497.

Hannaneh Akrami

Matroids are equitable

We show that if the ground set of a matroid can be partitioned into $k \geq 2$ bases, then for any given subset S of the ground set, there is a partition into k bases such that the sizes of the intersections of the bases with S may differ by at most one. This settles the matroid equitability conjecture by Fekete and Szabo (Electron. J. Comb. 2011) in the affirmative. We also investigate equitable splittings of two disjoint sets S_1 and S_2, and show that there is a partition into k bases such that the sizes of the intersections with S_1 may differ by at most one and the sizes of the intersections with S_2 may differ by at most two; this is the best possible one can hope for arbitrary matroids. We also derive applications of this result into matroid constrained fair division problems. We show that there exists a matroid-constrained fair division that is envy-free up to one item if the valuations are identical and trivalued additive. We also show that for bi-valued additive valuations, there exists a matroid-constrained allocation that provides everyone their maximin share.

Kristóf Bérczi

Interaction between skew-representability, tensor products, extension properties, and rank inequalities

Skew-representable matroids form a fundamental class in matroid theory, bridging combinatorics and linear algebra. Since deciding skew-representability is computationally intractable, much effort has been focused on identifying necessary or sufficient conditions for a matroid to be skew-representable. In this talk, we introduce a new approach to studying skew-representability and structural properties of matroids and polymatroid functions via tensor products. We provide a characterization of skew-representable matroids, as well as of those representable over skew fields of a given prime characteristic, in terms of tensor products. As an application of the tensor product framework, we give a new proof of Ingleton's inequality and, more importantly, derive the first known linear rank inequality for folded skew-representable matroids that does not follow from the so-called common information property.

Daniel Blankenburg

An efficient algorithm for minimizing ordered norms in fractional load balancing

We study the problem of minimizing an ordered norm of a load vector (indexed by a set of d resources), where a finite number n of customers c contribute to the load of each resource by choosing a solution x_c in a convex set $X_c \in \mathbb{R}^d_{\geq 0}$; so we minimize $||\sum_c x_c||$ for some fixed ordered norm $||\cdot||$. We devise a randomized algorithm that computes a $(1+\varepsilon)$-approximate solution to this problem and makes, with high probability, $\mathcal{O}(n+d)(\varepsilon^{-2} + \log\log d)(\log d + \log n)$ calls to oracles that minimize linear functions (with non-negative coefficients) over X_c.

While this has been known for the ℓ_∞ norm via the multiplicative weights update method, existing proof techniques do not extend to arbitrary ordered norms. For each customer, we define dynamic cost budgets, which evolve throughout the algorithm, to determine the allowed step sizes. This leads to non-uniform updates and may even reject certain oracle solutions. Using non-uniform sampling together with a martingale argument, we can guarantee sufficient expected progress in each iteration, and thus bound the total number of oracle calls with high probability.

Our algorithm uses a resource price mechanism that is motivated by the follow-the-regularized-leader paradigm, and is expressed by smooth approximations of ordered norms. We need and show that these have non-trivial stability properties, which may be of independent interest.

This is joint work with Antonia Ellerbrock, Thomas Kesselheim, and Jens Vygen.

Jannis Blauth

Toward optimal approximations for resource-minimization for fire containment on trees and non-uniform k-center

One of the most elementary spreading models on graphs can be described by a fire spreading from a burning vertex in discrete time steps. At each step, all neighbors of burning vertices catch fire. A well-studied extension to model fire containment is to allow for fireproofing a number B of non-burning vertices at each step. Interestingly, basic computational questions about this model are computationally hard even on trees. One of the most prominent such examples is Resource Minimization for Fire Containment (RMFC), which asks how small B can be chosen so that a given subset of vertices will never catch fire. Despite recent progress on RMFC on trees, prior work left a significant gap in terms of its approximability. We close this gap by providing an optimal 2-approximation and an asymptotic PTAS, resolving two open questions in the literature. Both results are obtained by first designing a PTAS for a smooth variant of RMFC, which is obtained through a careful LP-guided enumeration procedure. Moreover, we show that our new techniques, with several additional ingredients, carry over to the non-uniform k-center problem (NUkC), by exploiting a link between RMFC on trees and NUkC established by Chakrabarty, Goyal, and Krishnaswamy. This leads to the first approximation algorithm for NUkC that is optimal in terms of the number of additional centers that have to be opened. This is joint work with Christian Nöbel and Rico Zenklusen.

Chandra Chekuri

Buy-at-Bulk and hop-constrained network design

Buy-at-Bulk network design arises in telecommunication networks where economies of scale play a significant role. It has also played an important role in theoretical developments in approximation algorithm design. In this talk we will describe recent work that makes progress on two open questions. The first is on the integrality gap of a natural LP relaxation. The second is about fault tolerance. For both these the progress was made possible via connections to hop-constrained network design which is of independent interest and has seen a significant surge of activity in the recent past.

Based on joint work with Rhea Jain.

Linda Cook

200,000 colors suffice... for t-perfect graphs

Perfect graphs can be described as the graphs whose stable set polytopes are defined by their non-negativity and clique inequalities. In 1975, V. Chvátal defined an analogous class called t-perfect graphs, which are the graphs whose stable set polytopes are defined by their non-negativity, edge inequalities, and odd circuit inequalities. We show that t-perfect graphs are 200,000-colourable. This is the first finite bound on the chromatic number of t-perfect graphs, and answers a question of B. Shepherd from 1995.

This bound is probably not tight; M. Laurent and P. Seymour gave an example of a t-perfect graph requiring four colors in the 1990's and it is open whether all t-perfect graphs are 4-colorable. Our proof is mainly graph theoretic and uses techniques developed in the context of "chi-boundedness". In this talk we discuss this result and related open problems.

(Joint work with Maria Chudnovsky, James Davies, Sang-il Oum, Jane Tan)

Gérard Cornuéjols

The replication conjecture

The packing property for clutters is the analog of perfection in graph theory. In 1993 Conforti and Cornuejols proposed a replication conjecture for clutters with the packing property that is the counterpart of Lovasz' replication lemma for perfect graphs. This conjecture is still open. The dijoin clutter in weighted digraphs is particularly interesting in this context. For example, in 1980, Schrijver gave a counterexample to a conjecture of Edmonds-Giles which can be viewed as the analog of a minimally imperfect graph. Indeed Schrijver's example is minimally nonpacking. It was extended to an infinite family by Younger in 2001. In recent work, Abdi, Cornuejols and Dalirrooyfard show that Younger's family is key to understanding when dijoin clutters have the packing property, and they propose new conjectures!

Daniel Ebert

Nucleolus, happy nucleolus, and vehicle routing

We study the recently introduced fair division concept of the happy nucleolus for cost allocation among players in a cooperative game. The happy nucleolus applies the same fairness criterion as the well-established nucleolus but with reduced total value. Still, we show that the relation between the two concepts is quite involved, and intuitive properties do not hold. Further, we show how to get rid of certain linear subspace avoidance constraints that frequently appear in (happy) nucleolus computation. Motivated by this, we design a heuristic to efficiently compute the happy nucleolus of vehicle routing games, applied in practice as part of the BonnTour project.

This is joint work with Antonia Ellerbrock.

Sándor Fekete

Hard in theory, easy in practice? Solving hard optimization problems in geometry and elsewhere

A main objective of Computer Science and Computational Mathematics is to develop methods for solving challenging algorithmic problems. Often this quest encounters fundamental challenges, like NP-completeness - and resorts to ways in which these obstructions can be sidestepped, e.g., with polynomial-time approximation algorithms or methods for special classes with additional properties. This comes at the risk of focusing on proving mostly theoretical theorems, instead of developing methods for actually computing solutions.

In this talk, I will discuss these aspects for a number of NP-hard geometric optimization problems that are quite similar in flavor to the geometric Traveling Salesman Problem (TSP), but turn out to be of fundamentally different practical difficulty. These include Minimum-Weight Triangulation (MWT), Minimum-Dilation Triangulation (MDT) and Minimum-Area Polygonalizations (MAP). In addition, I will also sketch some recent insights into the perspectives of solving classical optimization problems with methods from quantum computing.

Michel Goemans

Revisiting the integrality ratio for ATSP

I'll visit the classical LP relaxation for ATSP, and summarize what is known and conjectures.

Peter Gritzmann

Anisotrotic diagrams, and the representation of polycrystals

We report on recent results for anisotrotoc diagrams with a view towards representing and analyzing polycrystalline materials. In particular, weight-constrained anisotropic clustering allows to compute diagram representations of polycrystals from data on the volume, center and moments of the grains which are available through tomographic measurements. Also we develop new coreset techniques which significantly accelerate the computations. This effect is demonstrated on 3D real-world data sets. (The talk is based on recent joint work with A. Alpers, M. Fiedler, F. Klemm.)

Sophia Heimann

A near-complete resolution of the exponential-time complexity of k-opt for the traveling salesman problem

The k-opt algorithm improves the current tour in each iteration by exchanging up to k edges. The algorithm continues until no further improvement of this kind is possible. For a long time, it remained an open question how many iterations the k-opt algorithm might require for small values of k, assuming the use of an optimal pivot rule. In this paper, we resolve this question for the cases $k = 3$ and $k = 4$ by proving that in both these cases an exponential number of iterations may be needed even if an optimal pivot rule is used. Combined with a recent result from Heimann, Hoang, and Hougardy (ICALP 2024), this provides a complete answer for all $k \geq 3$ regarding the number of iterations the k-opt algorithm may require under an optimal pivot rule. In addition we establish an analogous exponential lower bound for the 2.5-opt algorithm, a variant that generalizes 2-opt and is a restricted version of 3-opt. All our results hold for both the general and the metric traveling salesman problem. (This is joint work with Hung P. Hoang and Stefan Hougardy.)

Stephan Held

38 years of mathematical innovations in chip design

In 1987, the Research Institute for Discrete Mathematics in Bonn — under the leadership of then-director Bernhard Korte — initiated a groundbreaking collaboration with IBM focused on ”Combinatorial Optimization in Chip Design”. Hundreds of microchips were designed through the development and application of the ”BonnTools”. We will provide an overview of key milestones, current areas of active research, and open problems.

Stefan Hougardy

Fast algorithms for Euclidean perfect matching

We study the Euclidean minimum weight perfect matching problem on n points in the plane. Any deterministic approximation algorithm for this problem requires at least $\Omega(n \log n)$ time. We present an $O(n \log n)$-time algorithm achieving an approximation ratio of $O(n^{0.206})$, improving the previous best bound of $n/2$. We also extend our approach to higher fixed dimensions. This is joint work with Karolina Tammemaa.

Sharat Ibrahimpur

Stochastic load balancing with machine reservations

We introduce a novel variant of stochastic load balancing that enables a quantitative trade-off between the practical benefits of non-adaptive policies and their performance limitations. Our model describes a solution in two stages. In the first stage, given only job-size distributions, we reserve a set of at most k machines for each job (a k-reservation). In the second stage, after observing job-size realizations, we assign each job to one of its reserved machines (a consistent assignment). The goal is to minimize the expected makespan. If $k = 1$, we get the standard stochastic load balancing problem of finding a non-adaptive assignment with minimum expected makespan, and if k is equal to the number of machines, then we obtain an all-powerful omniscient optimum that can tailor the assignment arbitrarily to the job-size realizations.

We give a number of results that quantify this tradeoff. Most saliently, we show that in the setting of identical machines, a 2-reservation suffices to achieve a constant factor approximation to the omniscient optimum, establishing a “power-of-2-choices” result for stochastic load balancing. We also show that this no longer holds true in the more challenging setting of related machines. Nonetheless, we give a number of positive algorithmic results for this setting, including a bicriteria $O(1)$ approximation, and an algorithm that computes a 2-reservation of cost at most constant times what the adaptive optimum can achieve.

Joint work with David Aleman Espinosa, Naveen Garg, Neil Olver, and Chaitanya Swamy.

Ravindran Kannan

Random projections and distance between polytopes

We prove generalizations of two classical theorems of convex geometry, namely the Separating Hyperplane theorem and the Johnson-Lindenstrauss theorem. We prove:

1. Random Separating Hyperplane Theorem
   (Chiranjib Bhattacharyya, Ravi Kannan, Amit Kumar)
   Suppose K_1, K_2 are two polytopes in $\mathbf{R}^d$ each of diameter ≤ 1 and with poly many vertices. Suppose also Minimum $|x-y|, x \in K_1, y \in K_2$ is $\delta \in \Omega(1)$. Then, with probability at least $1/poly_\delta$, a random hyperplane separates K_1, K_2 by at least $c\delta/\sqrt{d}$.
2. Random projections preserve inter-polytopes distances
   (Ravi Kannan, Nikhil Srivatsava)
   Suppose we have a set of polytopes $K_1, K_2, \ldots, K_n$ in $\mathbf{R}^d$, each with at most poly many vertices and diameter ≤ 1 with each pair separated by $\delta \in (0,1)$. Suppose V is a subspace spanned by m iid Gaussian vectors, where,
   $$m \geq \log(nk)/\delta^2\varepsilon^2.$$
   Then, with high probability, for every $i, j \in [n]$, the distance in the projection to V between K_i and K_j is within relative error ε of $\sqrt{m}/\sqrt{d}$ times distance between them in $\mathbf{R}^d$.

The proofs are relatively simple and the talk will describe the intuition. Some applications will also be described.

Alexandra Lassota

A convoluted situation: fine-grained algorithms and complexity through the lens of min-plus convolution

In recent years, various approaches to combinatorial problems have entered the fine-grained toolbox. Min-plus convolution is one such problem that plays a central role in this development. I will present an overview and the current open problems for this problem including P-in-FPT and extension complexity. This talk is based on joint work with Cornelius Brand and Martin Koutecký.

Monique Laurent

Semidefinite approximations for bicliques and biindependent pairs

We investigate some graph parameters dealing with biindependent pairs in bipartite graphs, with close relationships to bicliques in general graphs. Deciding whether a bipartite graph has a maximum independent set that is balanced (i.e., with the same number of nodes on each side of the bipartition) is shown to be NP-complete.

This implies, in particular, NP-hardness of computing the maximum ratio (sum of sizes over product of sizes) for biindependent pairs. These hardness results motivate introducing semidefinite programming bounds for these various graph parameters, which can be seen as natural variations of the Lovász ϑ-number. We also formulate closed-form eigenvalue bounds and show relationships among them as well as with earlier spectral parameters by Hoffman, Haemers (2001) and Vallentin (2020). Based on joint work with Sven Polak and Luis Felipe Vargas.

Jan Karel Lenstra

A historical note on the complexity of scheduling problems

In 1972 E.M. Livshits and V.I. Rublinetsky published a paper in Russian, in which they presented linear-time reductions of the partition problem to a number of scheduling problems. Unaware of complexity theory, they argued that, since partition is not known to have a simple algorithm, one cannot expect to find simple algorithms for these scheduling problems either. Their work did not go completely unnoticed, but it received little attention and no recognition. I will describe the approach and review the results.

Siyue Liu

Approximately packing dijoins via nowhere-zero flows

In a digraph, a dicut is a cut where all the arcs cross in one direction. A dijoin is a subset of arcs that intersects each dicut. Woodall conjectured in 1976 that in every digraph, the minimum size of a dicut equals to the maximum number of disjoint dijoins. However, prior to our work, it was not even known if at least 3 disjoint dijoins exist in an arbitrary digraph whose minimum dicut size is sufficiently large. By building connections with nowhere-zero (circular) k-flows, we prove that every digraph with minimum dicut size τ contains τ/k disjoint dijoins if the underlying undirected graph admits a nowhere-zero (circular) k-flow. The existence of nowhere-zero 6-flows in 2-edge-connected graphs (Seymour 1981) directly leads to the existence of $\tau/6$ disjoint dijoins in any digraph with minimum dicut size τ, which can be found in polynomial time as well. The existence of nowhere-zero circular $(2+1/p)$-flows in $6p$-edge-connected graphs (Lovász et al 2013) directly leads to the existence of $\tau \cdot p/(2p+1)$ disjoint dijoins in any digraph with minimum dicut size tau whose underlying undirected graph is $6p$-edge-connected. This is joint work with Gérard Cornuéjols and R. Ravi.

László Lovász

Graph limits, matroid limits, and greedoids

Graph limit theory has been around for a couple of decades. In the last couple of years, an extension to a limit theory of matroids began to emerge. This suggests that a limit theory of greedoids might be interesting. I will formulate some possible approaches.

Haoyuan Ma

Optimal path following in the ℓ_2-neighbourhood

We show that the trust region interior point method (TR-IPM) by Lan, Monteiro and Tsuchiya (SIAM J. Optim. 2009) is optimal for ℓ_2-path following up to a constant factor. Namely, we show that the iteration complexity of this algorithm is within a constant factor of the straight line complexity of the ℓ_2-neighborhood, i.e., the minimum number of segments of any piecewise linear curve traversing this neighborhood of the central path. Previously, it was shown by Allamigeon, Dadush, Loho, Natura, and Végh (SIAM J. Comput. 2025) that the iteration complexity of the trust region algorithm is within $O(n^{1.5}\log n)$ of the straight line complexity of the wide neighborhood; our result improves this to a constant factor when in the ℓ_2-neighborhood.

Lan, Monteiro and Tsuchiya only gave a weakly polynomial algorithm for solving the trust region problem, and left it as an open question to develop a strongly polynomial algorithm. We resolve this question by presenting a new strongly polynomial algorithm that solves a parametric minimum norm problem to a very high accuracy. As a result, each iteration of our TR-IPM can be implemented in strongly polynomial deterministic $O(n^3)$ time.

Matthias Mnich

Fast approximation schemes for related machine scheduling

A fundamental problem in scheduling is to assign n jobs to m machines of varying speeds, with the objective of computing a scheduling with minimum makespan. Many different approximation schemes have been proposed for this problem in the past three decades, which compute $(1+\varepsilon)$-approximate schedules with smaller and smaller dependencies on n, m and ε. We continue this successful line of research and contribute yet another approximation scheme whose run time narrows the gap to what is known for the important special case when all machines have the same speed.

Bento Natura

Linear interior-point methods

We study algorithms for linear programs of the form $\min c \cdot x, Ax = b, x \geq 0$, that access the right-hand side b and objective c only through linear comparisons. An algorithm that operates under this restriction is called a linear algorithm. Such an algorithm can query an oracle which, given vectors u and v and scalars z and y, returns the signs of $u \cdot b + z$ and $v \cdot c + y$. The simplex method, as well as several known strongly polynomial combinatorial algorithms, can be implemented in this model. We show that interior-point methods can likewise be adapted to run as linear algorithms, which yields faster algorithms for several classes of linear programs and, through the framework of Norton, Plotkin, and Tardos, extends the family of problems that admit strongly polynomial algorithms.

Meike Neuwohner

Approximation schemes for planar graph connectivity problems

The k-Edge-Connected Subgraph problem and the k-Connectivity Augmentation problem are among the most basic Network Design problems and, consequently, have been heavily studied. Due to their approximation hardness, the gold standard in terms of approximation guarantee are strong constant factors. Interestingly, this approximation hardness does not carry over to planar graphs. In particular, the 2-Edge-Connected Subgraph problem admits a PTAS on planar graphs. However, the used techniques are very different from the celebrated Baker's framework, which is a standard way to design PTASs for planar graphs. The main obstacle of using Baker's technique in its classical form is that it requires a certain locality of the problem. However, k-edge/vertex-connectivity are global properties. We present a novel, and arguably clean, way to extend Baker's framework to deal with larger connectivity requirements. Based on this, we obtain a PTAS for the k-Edge-Connected Subgraph problem and its vertex analog, even with costs, as long as the max-to-min cost ratio is bounded by a constant. Moreover, together with further insights, we obtain a PTAS for the k-Connectivity Augmentation problem in the same cost setting. We complement this with an NP-hardness result for planar augmentation, showing that all our results are essentially tight. This is joint work with Vera Traub and Rico Zenklusen.

Luise Puhlmann

Approximating Asymmetric A Priori TSP beyond the adaptivity gap

In Asymmetric A Priori TSP (with independent activation probabilities) we are given an instance of the Asymmetric Traveling Salesman Problem together with an activation probability for each vertex. The task is to compute a tour that minimizes the expected length after short-cutting to the randomly sampled set of active vertices. We prove a polynomial lower bound on the adaptivity gap for Asymmetric A Priori TSP. Moreover, we show that a poly-logarithmic approximation ratio, and hence an approximation ratio below the adaptivity gap, can be achieved by a randomized algorithm with quasi-polynomial running time. To achieve this, we provide a series of polynomial-time reductions. First we reduce to a novel generalization of the Asymmetric Traveling Salesman Problem, called Hop-ATSP. Next, we use directed low-diameter decompositions to obtain structured instances, for which we then provide a reduction to a covering problem. Eventually, we obtain a polynomial-time reduction of Asymmetric A Priori TSP to a problem of finding a path in an acyclic digraph minimizing a particular objective function, for which we give an $O(\log n)$-approximation algorithm in quasi-polynomial time. This is joint work with Manuel Christalla and Vera Traub.

Dieter Rautenbach

A faster algorithm for independent cut

The previously fastest algorithm for deciding the existence of an independent cut had a runtime of $\mathcal{O}^*(1.4423^n)$, where n is the order of the input graph. We improve this to $\mathcal{O}^*(1.4143^n)$. In fact, we prove a runtime of $\mathcal{O}^*\left(2^{(\frac{1}{2}-\alpha_\Delta)n}\right)$ on graphs of order n and maximum degree at most Δ, where $\alpha_\Delta = \frac{1}{2+4\lfloor\frac{\Delta}{2}\rfloor}$. Furthermore, we show that the problem is fixed-parameter tractable on graphs of order n and minimum degree at least βn for some $\beta > \frac{1}{2}$, where β is the parameter.

R. Ravi

Two matching vignettes

A bipartite graph has a perfect proportional allocation if one can assign positive weights to right-hand nodes such that fractionally allocating each left-hand node to its neighbors in proportion to these weights yields a fractional perfect matching. With Daniel Hathcock, we proved that a bipartite graph has a perfect proportional allocation if and only if it is matching covered.

In a second result with Michele Conforti and Rafi Hassin, we consider an undirected graph with K edge-disjoint s-r paths (colored red) and K edge-disjoint s-t paths (colored teal), where edges may have both colors. We show that such graphs always contain K edge-disjoint r-t paths, each with a red prefix followed by a teal suffix, via a reduction to stable matchings.

András Recski

Graphicness-preserving strong maps of matroids

Let w be a real-valued weight function on the vertex set of a connected graph G satisfying $\sum w(v) = 0$. A 2-component forest is symmetric if $\sum w(v) = 0$ holds for the two components as well. The asymmetric 2-component forests form the bases of a matroid $S(G, w)$. This is a strong map of the cycle matroid of G. We characterize the universal graphs (which are mapped into graphic matroids by every weight function) and the universal functions (which map every graph into graphic matroids); then the potential graphs (which can be mapped into graphic matroids by some non-universal weight functions) and the potential weight functions (which can map some non-universal graphs into graphic matroids). As a byproduct, we characterize those matroids whose truncation is graphic. Finally, we present an engineering problem that motivated these studies - the “happy ending” of this application took place in Bonn in 1992.

Lisa Sauermann

Asymptotically-tight packing and covering with transversal bases in Rota's basis conjecture

Rota's basis conjecture from 1989 asserts that, given any n bases $B_1, \ldots, B_n$ of a matroid of rank n, one can find a collection of n disjoint transversal bases. In other words, this means that the union $B_1 \cup \cdots \cup B_n$ can be decomposed into n new bases of the matroid, each consisting of exactly one element from each of the original bases $B_1, \ldots, B_n$. In this talk, we discuss some progress towards this famous conjecture, showing that the union $B_1 \cup \cdots \cup B_n$ contains $(1 - o(1))n$ disjoint transversal bases, and also that the union $B_1 \cup \cdots \cup B_n$ can be covered by $(1 + o(1))n$ transversal bases. Joint work with Richard Montgomery.

Niklas Schlomberg

Packing cycles in planar and bounded-genus graphs

We devise constant-factor approximation algorithms for finding as many disjoint cycles as possible from a certain family of cycles in a given planar or bounded-genus graph. The family of cycles under consideration must satisfy two properties: it must be uncrossable and allow for a certain oracle access. Our setting generalizes many problems that were studied separately in the past. For example, three families that satisfy the above properties are (i) all cycles in a directed or undirected graph, (ii) all odd cycles in an undirected graph, and (iii) all cycles in an undirected graph that contain precisely one demand edge, where the demand edges form a subset of the edge set. The latter family (iii) corresponds to the classical disjoint paths problem in fully planar and bounded-genus instances. Furthermore, we obtain approximate min-max theorems of the Erdős-Pósa type.

This talk is partly based on joint work with Hanjo Thiele and Jens Vygen but also contains new results with improved ratios.

András Sebő

Odd paths, cycles and cuts: connections and frontiers

Minimizing the weight of edge-sets in graphs under parity constraints is a challenging area of combinatorial optimization as witnessed by the binary hypergraph chapter of Schrijver's book Combinatorial Optimization [Chapter 80]. This talk wishes to clarify the interconnections among some key graph theory problems in this field, establishing new results on their computational complexity:

This framework contains, for instance, open cases of the Max Cut problem in – not necessarily orientable – surfaces, that we are exploring with Éric Colin de

Verdière, Frédéric Meunier and Matěj Stehlík. The notable question of finding minimum odd paths for conservative weightings asked by Lovász (Open Problem 27 in Schrijver's above mentioned book, Volume 3) is a general hat for several problems we are interested in, but turns out, unfortunately, to be NP-hard; fortunately, this negative result has led to a significant reorganization of the relations between problem classes. Our work, in collaboration with Ildikó Schlotter, traces the border between NP-hard and polynomial solvable cases, and establishes connections with edge-disjoint path problems in digraphs.

Tractable problems and open questions lead us to the shortest odd cycle problem in conservative graphs, which, in the cardinality case, was shown by Geelen an Kapadia to be in RP. The frontier of NP-hardness appears between this, and the variant requiring cycles through a specified vertex. Ongoing research with Erika Bérczi-Kovács, Gergely Csáji and Alpár Jüttner demonstrates that the planar special case of this latter problem is polynomially solvable using the algebraic tool of Pfaffians, inviting new questions, among them about the existence of a combinatorial algorithm, and about the boundaries of tractability in planar graphs.

Bruce Shepherd

Greedy algorithms for downwards closed set systems and polytopes

A collection $\mathcal{F}$ of subsets of a ground set V is an *independence family* if it is downwards-closed. For $S \subseteq V$, $\mathcal{F}$'s *upper rank* is $ur(S) := \max\{|F| : F \subseteq S, F \in \mathcal{F}\}$ and its *lower rank* is $lr(S) := \min\{|F| : F \text{ is maximal subject to } F \subseteq S, F \in \mathcal{F}\}$. An independence family is a *p-system* if $ur(S) \leq p \cdot lr(S)$ for each $S \subseteq V$. We discuss the work of Korte, Hausmann and Jenkyns who showed (among other things) that p-systems have the following property. For any objective vector $w \in \mathbb{R}^V$, the greedy algorithm always produces solutions within a factor p of optimum for the problem: $\max\{w(S) : S \in \mathcal{F}\}$. This settled a conjecture of Nemhauser at the time.

Chaitanya Swamy

Almost tight additive guarantees for k-edge connectivity

We consider the k-edge connected spanning subgraph (kECSS) problem, where we are given an undirected graph with nonnegative edge costs, and we seek a minimum-cost subgraph that is k-edge connected, i.e., there are k edge-disjoint paths between every pair of nodes. For even k, we present a polytime algorithm that computes a $(k-2)$-edge connected subgraph of cost at most the optimal value of the natural LP-relaxation for kECSS; for odd k, this leads to a $(k-3)$-edge connected subgraph of cost at most the LP optimum. Since kECSS is APX-hard for all $k \geq 2$, the tightest connectivity guarantee one can hope for without exceeding the optimal value is $(k-1)$-edge connectivity, so our results are nearly tight. They also significantly improve upon the recent work of Hershkowitz et al., both in terms of solution quality and the simplicity of algorithm and its analysis. Our result is obtained using iterative rounding, with additional insights involving uncrossing tight sets for kECSS. A slight variant of our approach yields a $(k-1)$-edge connected subgraph of cost at most 1.5 times the LP optimum; with unit edge costs, the cost guarantee improves to $(1+4/3k)$ times the LP optimum, which improves upon the state-of-the-art approximation for unit edge costs, but with a unit loss in edge connectivity. The kECSS-result also yields results for the k-edge connected spanning multigraph (kECSM) problem, where multiple copies of an edge can be selected. Our techniques extend to the degree-bounded versions of kECSS and kECSM, wherein we also impose degree lower- and upper- bounds on the nodes.

Joint work with Nikhil Kumar.

Zoltán Szigeti

Augmenting a hypergraph to have a matroid-based (f,g)-bounded (α,β)-limited packing of rooted hypertrees

The main result on graphs extends the theorem of Katoh and Tanigawa on matroid-based packing of rooted trees by characterizing the existence of such a packing satisfying the following further conditions: for every vertex v, there are a lower bound $f(v)$ and an upper bound $g(v)$ on the number of trees rooted at v and there are a lower bound α and an upper bound β on the total number of roots. We also answer the hypergraphic version of the problem. Furthermore, we are able to solve the augmentation version of the latter problem, where the goal is to add a minimum number of edges to have such a packing. The methods developed to solve these problems may have other applications in the future.

It is a join work with my Phd student Pierre Hoppenot, see https://arxiv.org/abs/2412.03363

Vera Traub

Unsplittable cost flows from unweighted error-bounded variants

A famous conjecture of Goemans on single-source unsplittable flows states that one can turn any fractional flow into an unsplittable one of no higher cost, while increasing the load on any arc by at most the maximum demand. Despite extensive work on the topic, only limited progress has been made. Recently, Morell and Skutella suggested an alternative conjecture, stating that one can turn any fractional flow into an unsplittable one without changing the load on any arc by more than the maximum demand.

We show that their conjecture implies Goemans' conjecture (with a violation of twice the maximum demand). To this end, we generalize a technique of Linhares and Swamy, used to obtain a low-cost chain-constrained spanning tree from an algorithm without cost guarantees. Whereas Linhares and Swamy's proof relies on Langrangian duality, we provide a very simple elementary proof of a generalized version, which we hope to be of independent interest. Moreover, we show how this technique can also be used in the context of the weighted ring-loading problem, showing that cost-unaware approximation algorithms can be transformed into approximation algorithms with additional cost guarantees.

This is joint work with Chaitanya Swamy, Laura Vargas Koch, and Rico Zenklusen.

Laura Vargas Koch

Approximating Graphic Multi-Path TSP and Graphic Ordered TSP

We present a simple 2-approximation algorithm for the Graphic Multi-Path TSP, improving upon the best known factor of 2.214 in the general case. Our algorithm is based on sampling paths from a decomposition of the flow corresponding to the optimal solution to the LP relaxation of the problem, and connecting the left-out vertices with doubled edges. The cost of the latter is twice the optimum in the worst case; we show how the cost of the sampled paths can be absorbed into it without increasing the approximation factor. Furthermore, we prove that any below-2 approximation algorithm for the special case of the problem where each source coincides with its corresponding sink yields a below-2 approximation algorithm for Graphic Multi-Path TSP. Finally, we demonstrate that our ideas can be utilized to give a factor 1.791-approximation algorithm for Ordered TSP in graphic metrics, improving on the 1.868-approximation algorithm known for general metrics. This is joint work with Morteza Alimi, Niklas Dahlmeier, Tobias Mömke and Philipp Pabst.

László Végh

From incremental transitive cover to strongly polynomial maximum flow

We provide faster strongly polynomial time algorithms solving maximum flow in structured n-node m-arc networks. Our results imply an an $n^{\omega+o(1)}$-time strongly polynomial time algorithms for computing a maximum bipartite b-matching where $\omega < 2.38$ is the matrix multiplication constant. Additionally, they imply an $m^{1+o(1)}W$-time algorithm for solving the problem on graphs with a given tree decomposition of width W.

We obtain these results by strengthening and efficiently implementing an approach in Orlin's state-of-the-art $O(mn)$ time maximum flow algorithm from 2013. We develop a general framework that reduces solving maximum flow with arbitrary capacities to (1) solving a sequence of maximum flow problems with polynomial bounded capacities and (2) dynamically maintaining a size-bounded supersets of the transitive closure under edge additions; we call this incremental transitive cover. Our applications follow by leveraging recent weakly polynomial, almost linear time algorithms for maximum flow due to Chen et al. (2022) and van den Brand et al. (2013), and by developing new incremental transitive cover data structures for special cases. This is joint work with Daniel Dadush, James Orlin, and Aaron Sidford.

Santosh S. Vempala

The complexity of convex optimization with membership oracles

We consider the problem of minimizing a convex function over a convex set specified by an evaluation oracle for the function and a membership oracle for the set. We give a simple algorithm which solves this problem using nearly n^2 oracle calls and nearly n^3 additional arithmetic operations for a problem in n-dimensional space. This implies more efficient reductions among the five basic oracles for convex sets and functions defined by Grötschel, Lovász and Schrijver.

This is joint work with Yin Tat Lee and Aaron Sidford.

Stefan Weltge

Multiplicative assignment with upgrades

We study a problem related to submodular function optimization and the exact matching problem for which we show a rather peculiar status: its natural LP-relaxation can have fractional optimal vertices, but there is always also an optimal integral vertex, which we can also compute in polynomial time. More specifically, we consider the multiplicative assignment problem with upgrades in which we are given a set of customers and suppliers and we seek to assign each customer to a different supplier. Each customer has a demand and each supplier has a regular and an upgraded cost for each unit demand provided to the respective assigned client. Our goal is to upgrade at most k suppliers and to compute an assignment in order to minimize the total resulting cost. This can be cast as the problem to compute an optimal matching in a bipartite graph with the additional constraint that we must select k edges from a certain group of edges, similar to selecting k red edges in the exact matching problem. Also, selecting the suppliers to be upgraded corresponds to maximizing a submodular set function under a cardinality constraint. Our result yields an efficient LP-based algorithm to solve our problem optimally. In addition, we provide also a purely strongly polynomial-time algorithm for it. As an application, we obtain exact algorithms for the upgrading variant of the problem to schedule jobs on identical or uniformly related machines in order to minimize their sum of completion times, i.e., where we may upgrade up to k jobs to reduce their respective processing times.

David P. Williamson

The 4/3 conjecture for the traveling salesman problem: a status update

The 4/3 conjecture for the traveling salesman problem (TSP) states that the standard linear programming relaxation for the TSP has an integrality gap of 4/3 in the case of the symmetric TSP instances that obey the triangle inequality. In this talk, I will survey what we know about the status of this conjecture and special cases for which we know that the conjecture is true.

Exhibitions at the Arithmeum

Each of the two tours is offered in three possible time slots. Please **sign up for them as early as possible** if you want to join.

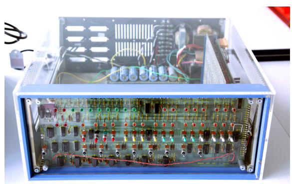
Calculating then and now

The Arithmeum's permanent exhibition presents the development of mechanical calculation in chronological order, beginning with early calculating aids such as the first counting stones, known as calculi, early writing tablets with quantity representations from Mesopotamia, early abacuses, medieval counting pennies and a calculating table. Visitors learn about Napier's bones as a multiplication aid and can try their hand at calculating on Wilhelm Schickard's oldest calculating machine. The first four-species calculating machine, i.e. the machine that could actually solve all four basic arithmetic operations mechanically, was built by Gottfried Wilhelm Leibniz. The last uniquely manufactured calculating machines by Stanhope, Hahn, Müller, Schuster and Auch are displayed before the tour moves on to series and industrial production. The early days of computing with Babbage and Hollerith are documented as well. There is also a display case in which rare and fascinating works from the bibliophile book collection are exhibited. In addition, the beginnings of cryptography and the possibilities of computer-assisted decryption are explained with the famous Enigma. The 'computing today' section makes the connection to the current scientific work of the Research Institute for Discrete Mathematics. Here, visitors can learn about the design and manufacture of microprocessors as well as the question of how microprocessors are mathematically calculated today before they can be manufactured.

Early Computers and PCs

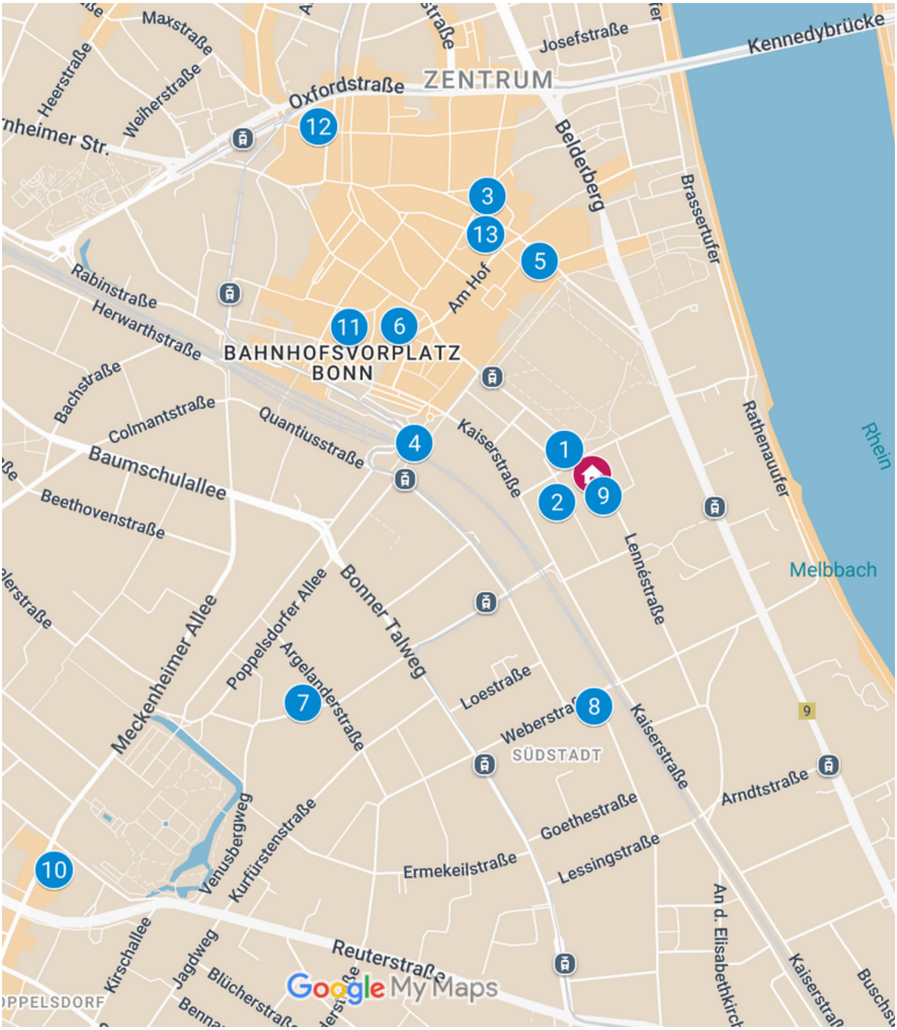
In the past 20 years, the Arithmeum has been able to assemble an outstanding collection of early computers and PCs. Starting with punched card counting and sorting machines like the D11, proceeding to minicomputers like the PDP 8 and PDP 11, and thence to the first tabletop computers like the Olivetti Programma 101, Altair, IMSAI and HP, and PCs like the Apple 1, IBM 5100, Commodore Pet, C64, Amiga, Atari and NEXT – all these objects are presented and most of them are demonstrated live with original software. A walk through this viewing depot shows the path from the first computers all the way to the present-day PC in the form of smartphones and desktops, without which our daily life is unimaginable. The giant step from mechanics to microelectronics can be experienced in this impressive viewing depot.





Commodore CBM 710, Apple Macintosh Plus 1, Altair 8800 MITS ©Arithmeum

Restaurant Recommendations



 Arithmeum

For a quick snack

1. Café Orange, €, 9:00–19:00
2. Kostbar, €, 11:00–15:00, soups and salads, only cash
3. Markt*, €, various street food stands
4. Kichererbse, €, 10:30–21:00, falafel takeaway imbiss, only cash

Restaurants

5. Ichiban Sushibar, €€, TU-FR 12:00–22:00
6. Tuscolo*, €€, 11:30–23:30, pizza and pasta, place of conference dinner
7. Mam-Mam, €€, TU-FR 12:00–15:00, 17:00–21:30, Vietnamese
8. Schumann's, €€€, 12:00–23:00, upscale western cuisine, reservations recommended
9. Il Punto, €€€€, MO, TU, WE, FR 12:00–14:30, 18:00–22:00, Italian, Korte's favourite, reservations recommended
10. ESSKALATION, €€, 11:00–17:00, vegan cuisine
11. Sion im Carré*, €€, 11:30–23:00, western cuisine
12. Brauhaus Bönnsch*, €€, 11:00–01:00, traditional Rhenish food and beer
13. BonnGoût*, €€, 10:00–23:00, French food

* = recommended for large groups

Program at a glance

	Monday	Tuesday	Wednesday	Thursday	Friday
9–10		Santosh Vempala		Vera Traub	R. Ravi
		Bento Natura		Daniel Ebert	Stefan Weltge
10–11		Haoyuan Ma	Commemoration Session	Linda Cook	Stefan Hougardy
		Coffee	Commemoration Session	Coffee	Coffee
11–12		Bruce Shepherd	Commemoration Session	Matthias Mnich	Gérard Cornuéjols
		Zoltán Szigeti	Commemoration Session	Sharat Ibrahimpur	Ahmad Abdi
12–13		Hannaneh Akrami	Lunch Reception	Daniel Blankenburg	Lászlo Lovász
			Lunch Reception		Closing
13–14			Lunch Reception		
	Registration		Lunch Reception		
14–15	Opening				
	Stephan Held	Dieter Rautenbach	Lisa Sauermann	Ravindran Kannan	
15–16	Jannis Blauth	Alexandra Lassota	Kristóf Bérczi	Peter Gritzmann	
	Laura Vargas Koch	László Végh	András Recski	Sándor Fekete	
16–17	Coffee	Coffee	Coffee	Coffee	
	David Williamson	András Sebő	Chandra Chekuri	Monique Laurent	
17–18	Sophia Heimann	Siyue Liu	Meike Neuwohner	Michel Goemans	
	Luise Puhlmann	Niklas Schlomberg	Chaitanya Swamy	Jan Karel Lenstra	
18–19	Welcome Reception				
	Welcome Reception				
19–20	Welcome Reception				
	Welcome Reception			Conference Dinner (Tuscolo)	
20–21				Conference Dinner (Tuscolo)	
				Conference Dinner (Tuscolo)	
21–22				Conference Dinner (Tuscolo)	
				Conference Dinner (Tuscolo)	

(hatched) = Arithmeum tours possible during these slots
(Wednesday 18:05–19:05, Thursday 13:15–14:15, Thursday 18:05–19:05)