SRS
SwissMAP Research Station in Les Diablerets

CROSSINGS

SwissMAP Research Station Magazine

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SRS SwissMAP Research Station in Les Diablerets

Edito

Welcome to the SwissMAP Research Station!

The SwissMAP Research Station (SRS) is a joint venture of the University of Geneva and ETH Zurich, established with the help of the Swiss National Science Foundation (SNSF) and of the National Centre of Competence in Research SwissMAP. It organises and hosts one-week events in Mathematics and Theoretical Physics, including Winter and Summer schools, as well as a small number of Outreach events.

The Station was founded in 2021, in the middle of the COVID-19 pandemic, and its first events were mostly held online with a very limited number of on-site participants. Since then, the SRS has gained in visibility, and in 2026 it is hosting 22 events ranging from international conferences and targeted workshops to schools geared towards PhD and Master students and Math camps for high school students. Another 21 events are scheduled for 2027.

The SRS is located in Les Diablerets, a mountain resort in the Swiss Alps, easily accessible by public transportation from both Geneva and Zurich. Our partner hotels readily welcome small- and big-scale events. With its bespoke lecture hall, equipped with 4 large sliding blackboards and 2 interactive screens, the Hotel Les Sources can accommodate conferences of up to 60 participants, while bigger events are hosted in the conference center *la Maison des Congrès*. Recording and streaming equipment is also provided, which allows for both on-site and online participation for the speakers as well as the audience. Conference participants also have access to other rooms available for discussions in smaller groups. In summertime, a blackboard installed in the yard of the Hotel Les Sources is very popular!

The applications for events to be held in 2028 are open, with the submission deadline set on October 10, 2026. The events will be selected by the SRS Scientific Council in the fall of 2026, with selection results communicated in December 2026 - January 2027. We hope to receive many exciting suggestions, and to make an excellent program for 2028 which will continue unfolding the SRS story started in 2021!

Anton Alekseev (UNIGE)
SRS Co-Director

The International Workshop on Automorphic Forms

by Claire Burrin (UZH)

Participants of the International Workshop on Automorphic Forms, held at the SwissMAP Research Station in September 2025 celebrating the seminar's five-year anniversary.

The study of automorphic forms is a venerable subject, with roots in 19th century mathematics, which today plays a central role in modern number theory. Since 2020, the weekly virtual *International Workshop on Automorphic Forms* invites speakers to present recent progress in the field, broadly construed to include its algebraic, analytic, computational, and geometric aspects. This breadth has been key to the seminar's success, which I joined as a co-organiser in 2022, and the seminar continues to thrive through the contributions of an active and truly international network of researchers.

To complement the online format, we celebrated the seminar's five-year anniversary with an in-person event: the *International Workshop on Automorphic Forms*, held at the SRS in September 2025. The workshop carried over the seminar's ambition to present a broad and modern view of the field, while fostering the kind of sustained interactions that only an in-person meeting can provide.

A recurring theme was the study of special values of L-functions and their conjectural interpretations, including instances of the Bloch–Kato and Gross conjectures. At the same time, advances in the analytic theory featured prominently, with new results on sup-norm bounds, subconvexity, and equidistribution problems in connection with quantum chaos. On the geometric side, several talks explored the structure of Shimura varieties and their special cycles, contributing to the far-reaching Kudla program at the interface of automorphic forms and arithmetic geometry, while other contributions highlighted connections to areas such as vertex algebras or mathematical physics.

These themes were reflected in a series of talks by researchers from a wide range of institutions and backgrounds. Edgar Assing (Bonn) presented new bounds toward the sup-norm problem, while Asbjørn Nordentoft (Paris) discussed refinements of equidistribution questions in the context of the Michel–Venkatesh program. Paloma Bengoechea (Barcelona) reported on recent progress on Kaneko's conjectures for the modular j-function, one of the most classical objects in the theory. On the arithmetic side, Aleksander Horawa (Oxford) described the first examples verifying cases of a conjecture of Gross, extending the philosophy of Waldspurger-type formulas to new settings. Eugenia Roşu (Leiden) presented recent advances in the Kudla program, deepening the connection between special cycles and modularity, while Yunqing Tang (Berkeley) introduced new approaches to the irrationality of special values of L-functions building on her work with Calegari and Dimitrov, illustrating how classical questions continue to inspire new techniques.

The workshop unfolded at a deliberately conversational pace, with discussions continuing well beyond the scheduled talks. Two days of steady rain may have helped as well. The focus on scientific exchange was remarkably supported by the attentive local staff and the SwissMAP team in Geneva, who did a splendid job in what I since describe as an organiser's dream conference. On a more personal note, I came to Les Diablerets with my six-month-old daughter in tow, carrying her in the baby carrier as she stared wide-eyed at the blackboard filled with formulas, occasionally punctuating a statement with a few well-timed coos. The welcoming and informal atmosphere of the workshop made this feel entirely natural. As the saying goes, it is never too early to learn automorphic forms!

The following recordings from the International Workshop on Automorphic Forms are available on the SRS playlist on the NCCR SwissMAP YouTube channel

- p-Adic Aspects of Maaß forms - Jan Vonk (Leiden University)
- On connections between modular forms and coding theory - Jolanta Marzec-Ballesteros (Adam Mickiewicz University)
- Rigid classes for SL(n) and p-adic families of modular forms - Martí Roset Julià (McGill University)
- p-adic Theta-functions and rigid meromorphic cocycles - Michael Alexander Daas (MPIM Bonn)
- On the geometric side of Arthur's trace formula - Pepijn Hulsbergen (Leipzig University)
- Additive twists of Maaß forms L-functions - Sandro Bettin (University of Genova)
- The arithmetic of power series and applications to irrationality - Yunqing Tang (UC Berkeley)
- Joint equidistribution of new forms - Asbjørn Nordentoft (University of Copenhagen)
- Symplectic Kloosterman Sums - Gilles Felber (Alfréd Rényi Institute of Mathematics)
- Teichmüller curves and Hilbert modular forms - Nicole Müller (GU Frankfurt)
- Hecke equidistribution in cryptography - Radu Toma (IMJ-PRG)
- Bloch-Kato conjecture for Asai L-functions on U(3) - Xiaoyu Zhang (University of Duisburg-Essen)
- The arithmetic of coefficients of certain automorphic forms on G2 - Aleksander Horawa (Oxford University)
- The Stark conjectures for cyclotomic extensions of complex cubic fields - Robin Zhang (Massachusetts Institute of Technology)
- On the GL(2) sup-norm problem in the level aspect - Edgar Assing (University of Bonn)
- Linking numbers and non-holomorphic Siegel modular forms - Mads Christensen (University College London)
- The Picard group of the Baily-Borel compactification of orthogonal Shimura varieties - Manuel Müller (TU Darmstadt)
- A dynamical approach to the Bombieri-Iwaniec method - Matthew Welsh (Michigan State University)
- CM values of Borcherds products on $X_0(N)^2$ - Mingkuan Zhang (TU Darmstadt)
- A Λ-adic Oda-Lift - Paul Kiefer (University of Antwerp)
- Elliptic curves and meromorphic modular forms - Pengcheng Zhang (MPIM Bonn)
- Minimal Trilinear Operators on Modular Forms - Shaul Zemel (Hebrew University of Jerusalem)
- Modularity from the point of view of vertex algebras and symplectic singularities - Sven Möller (University of Hamburg)

ALPS II: Modern Topics in Quantum Many-Body Physics, from Chaos to Integrability

by Rahel Baumgartner (UNIGE)

Participants of ALPS II at the SwissMAP Research Station, May 2025.

ALPS — Advanced Lectures in Physics in Switzerland — is a series of junior schools in theoretical physics, organised by young researchers, for young researchers. Each edition takes place at the SRS, and brings together participants, mostly PhD students, but also Master's students and early postdocs, from different areas of theoretical physics for a week of lectures, exercises, and informal scientific exchange.

The school was initiated by Vito Pellizzani (University of Oxford), whom I met during another SwissMAP event in Les Diablerets. The organizing team has grown and evolved across editions. This second edition was organised by Vito together with Adrien Florio (University of Bielefeld), Sara Murciano (from Université Paris-Saclay, who replaced the departing Donald Huber-Youmans), and me. We are all from different areas of physics, and that diversity is very much part of the school's identity, it feeds directly into the choice of topics and the kind of cross-community exchange we try to foster.

The second edition took place from May 25 to 30, 2025, and was centered on quantum many-body physics approached from three complementary angles: quantum chaos and the Sachdev-Ye-Kitaev model, lectured by Alexey Milekhin (University of Kentucky), hydrodynamics in quantum field theory presented by Akash Jain (University of Oxford), and weak integrability breaking and thermalization taught by Federica Maria Surace (University of Innsbruck).

The idea, both in the choice of topics and in the structure of each edition, is to offer three lecture

The Horizon Lecture: an open discussion panel closing ALPS II.

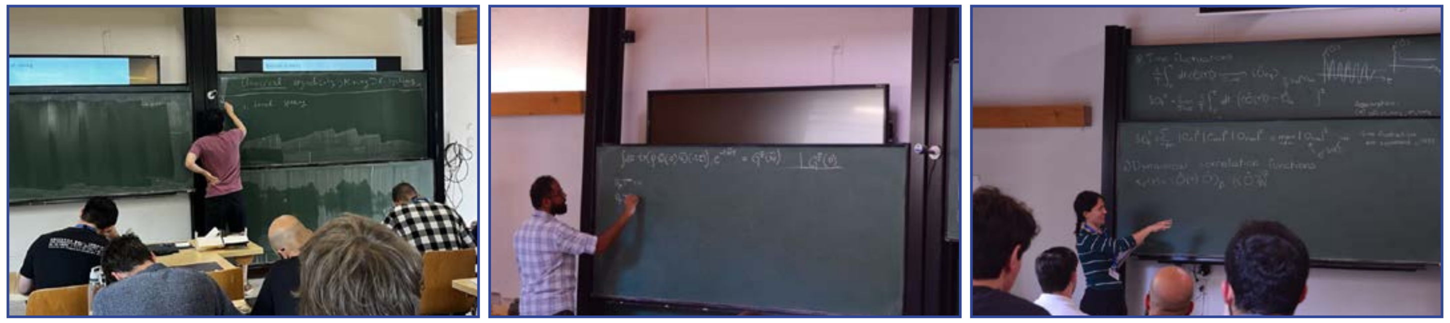
sets that together cover a range of subfields. Typically, and broadly speaking, one leaning more towards high-energy physics, one closer to condensed matter physics, and one with a more applied or computational flavor, including exercises that involve some programming. The hope is that each participant finds at least one course in their comfort zone, and is gently pushed into unfamiliar territory by the remaining ones.

The program also featured a colloquium by Romain Vasseur (UNIGE), who spoke about integrability and hydrodynamics from the perspective of his own current research, and the school closed with a panel discussion, called the "Horizon Lecture", where lecturers talked more openly about open questions, career trajectories, and what they find exciting right now.

In total, each lecturer taught for around six hours, spread over four sessions, plus an additional exercise session. This last component is something we put a lot of importance on: each lecturer designed a session around a recent paper or open question in their area, which students worked through in small groups. The tasks ranged from pencil-and-paper calculations to coding exercises, and students could choose and switch between sessions freely. It is something often underemphasized at PhD schools, and the feedback suggests it was one of the most appreciated parts of the program.

We received over 70 applications and selected 34 participants from 11 countries across 4 continents, with backgrounds ranging from condensed matter to quantum gravity. Thanks to the generous support of COMAD (UNIGE), we were able to partially cover travel expenses for several students coming from India, Australia, Ireland, and Poland, and to waive the registration fee for some of them. This kind of financial support feels important to us, keeping the school accessible to motivated students regardless of where they are based is very much in the spirit of what we are trying to do.

ALPS III returned to Les Diablerets from May 17 to 22, 2026. We were happy to have Catherine McCarthy (UNIGE) as a new member of the organizing team. Planning for a 2027 edition is already quietly underway, and we hope ALPS can grow into a recurring fixture for young theoretical physicists in Switzerland.



The lecturers of ALPS II in action.

Interview with Eva Cantoni (FSJM Training Camp)

From 27 to 29 June 2025, the SwissMAP Research Station hosted the FSJM (*Fédération Suisse des Jeux Mathématiques*) training camp in preparation for the International Final of the Championship of Mathematical and Logical Games. FSJM is a non-profit association promoting the study and practice of mathematics in Switzerland through recreational problem-solving activities, with particular attention to encouraging participation in MINT disciplines, especially among girls. In this interview, Eva Cantoni reflects on the camp's objectives and its broader impact on fostering engagement with mathematics.

The FSJM training camp was held at the SRS during the summer 2025. What was the initial motivation for organising this event there, and what were its main objectives?

The training camp was meant as preparation for the international final which took place last year in Tunisia. As such, it was motivated by the desire to create an environment that combines high-level mathematics with immersion and collaboration.

The camp aimed to train the qualified participants to the international final by strengthening their problem-solving skills, speed, and strategic thinking with the help of FSJM coaches and past participants to the championship. Beyond competition training, the goal was to expose participants to more advanced, creative and also playful approaches to mathematics, encouraging them to think flexibly and explore different solving techniques. Bringing young participants of different ages together in an immersive setting fostered collaboration, exchange of ideas, and peer learning. It also helped create motivation and a sense of belonging among participants who share the same passion. In addition to lots of fun!

It gathered 35 participants from across Switzerland, including 10 women, supported by a team of seven volunteer staff members, three of them women, including teachers and mathematics enthusiasts. The initiative is fully based on voluntary engagement, with all organisers and coaches contributing their time without remuneration.

The camp prepares participants for the International Final of the Championship. How do you approach this preparation? Beyond mathematical problem-solving itself, are there aspects such as strategy, mindset, or confidence-building that you consider essential?

On the technical side, participants were exposed to a wide variety of problem types similar to those they will encounter in the competition. This helps them develop flexibility and pattern recognition, as well as the ability to choose efficient solving methods under time constraints.

Success in the competition is not just about solving ability. Strategy plays an important role, for example, knowing how to manage time, which problems to start with, and when it's better to move on instead of getting stuck. Participants often face unfamiliar problems, so we encourage them to stay calm, be creative, and not lose confidence when something looks difficult at first. The camp environment helps participants gain confidence in their abilities, by working together and discussing ideas.

Math 4 Fun: A team competition open to everyone, organised by the FSJM.

In Tunisia, the Swiss delegation was very successful, with many podium finishes across the various categories. The program of the weekend included specific mathematical training, but not only. An outdoor escape game was organised, and a session of a team game, where the participants have to guess the rules.

During certain activities, participants of different ages were mixed into teams. This allowed younger participants to interact with university students and adults, often gaining confidence through collaboration and peer encouragement.

Who typically takes part in the training camp, and how would you describe the level and expectations at this stage of the competition?

All the participants to the Swiss final of the Championship who qualified to the international final were invited to participate to the camp. These include participants of all ages (including adults), but in practice children (from eight years on) and young adults (mostly university students) accept the invitation.

This specific setting means that the level is quite high. Participants are already very comfortable with logical reasoning and standard problem types, so during the camp we can focus on more challenging, less routine problems.

Participants are very actively engaged, trying different strategies, explaining their thinking, and learning from each other. There's a strong emphasis on curiosity and openness, being willing to explore new ideas and sometimes even struggle with difficult problems.

The multi-age format creates a distinctive dynamic: while training sessions are often organised by age group, other activities deliberately mix generations. This fosters mentorship, exchange and a strong team spirit among participants.

The FSJM promotes broad engagement with mathematics, including among girls and young students. How does this commitment shape the way the training camp is organised in practice?

We try to create an environment that is welcoming and inclusive for everyone. Even though participants are already high-level, it's important that everyone feels comfortable contributing, asking questions, and sharing ideas. We also pay attention to group

dynamics, encouraging collaboration in small groups within the same age groups.

Another important aspect is representation and role models. FSJM is aware that participation of girls tends to decrease during teenage years, and particular care is given to ensuring visible female role models among coaches and organisers, including younger women with whom participants may more easily identify.

Be it at the committee level or at the staff level, we make an effort to highlight diverse profiles, so that young persons, and especially girls, can more easily see themselves in the field of mathematics.

We also try to include a variety of problem types and formats, not just competitive exercises, but also more exploratory or discussion-based sessions. This helps show that mathematics is not only about performance, but also about creativity, curiosity, and enjoyment.

What does hosting such an event at the SRS bring compared to other possible settings?

The SRS allows a full experience. It is nicely located in the mountains, away from daily distractions, so that participants can really engage deeply with the activities. It is easily accessible by public transport. The facility offers good support at all levels (rooms, meals, well equipped conference room, nice personnel). In addition, the SwissMAP team facilitates and supports the organization of the event. The immersive setting contributes significantly to building group cohesion and creating a memorable shared experience.

Have you observed concrete examples of how participation in FSJM activities influences students' academic paths or their relationship to mathematics more broadly?

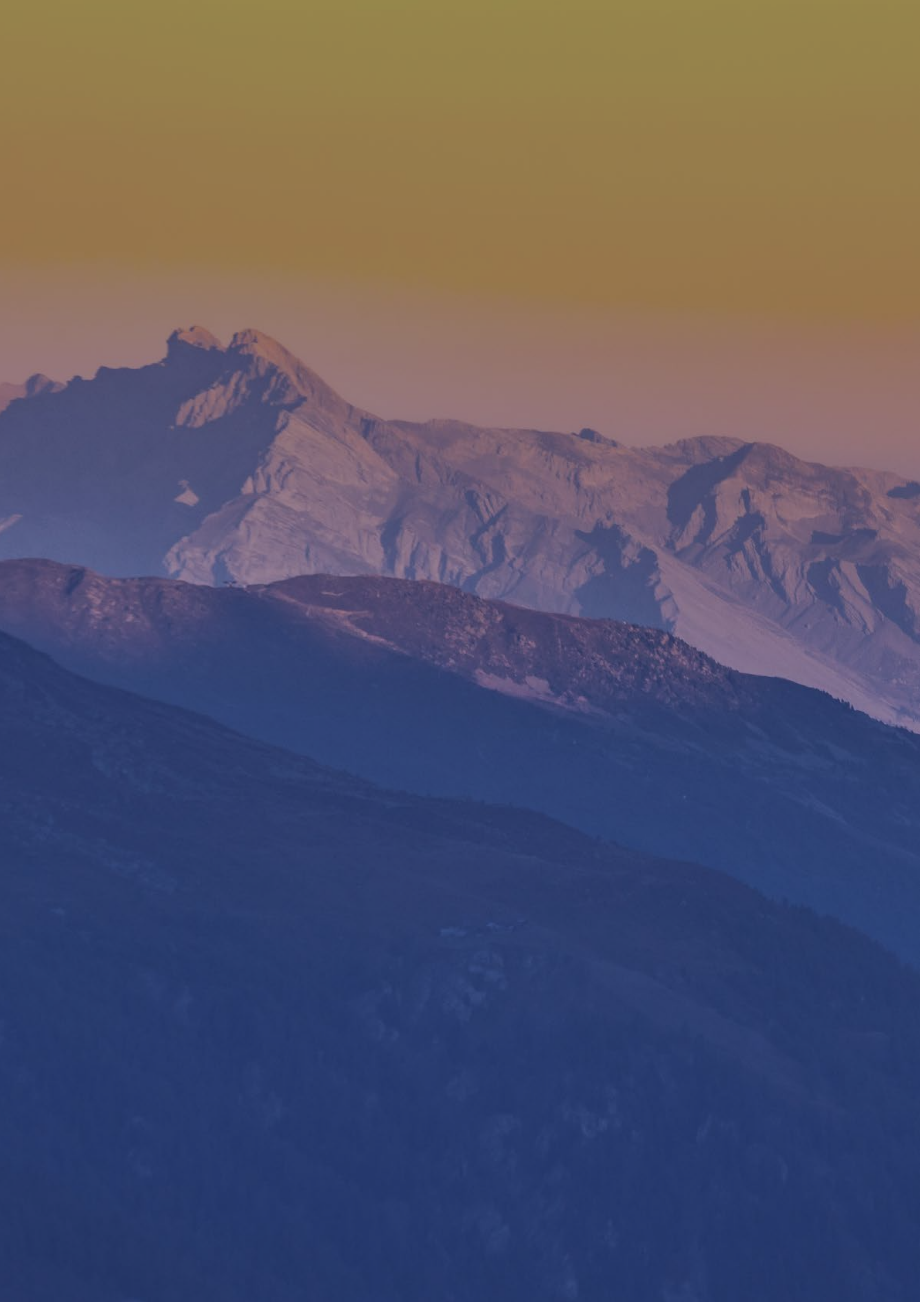
FSJM is deeply committed to promoting STEM disciplines at every possible opportunity, for example through initiatives such as the presence with a booth at MINT Vaud and at the Math'émerveille festival, and with our *mathematical suitcase*, which is intended to empower school teachers with additional practical activities around mathematics. We believe that any activity that highlights the beauty of mathematics and helps demystify it can play an important role in encouraging young people to engage with STEM fields. By showing that mathematics is not only rigorous but also creative, accessible, and even playful, we can change perceptions and spark curiosity.

Our goal is to contribute, in our own way, to a broader effort: helping more students feel confident exploring scientific paths and considering studies and careers in these areas. In that sense, we see our work as one small but meaningful building block in strengthening the future of STEM education.

Participants often remain connected beyond the camp itself, forming informal networks and friendships around their shared interest in mathematics.

Fun fact: we often see adults who are former participants in the championship returning to compete with their children once the children are old enough to take part.

Further information on the FSJM website: https://fsjm.ch



2025 SwissMAP Junior Researcher Prize Winners

We are pleased to announce the recipients of the second edition of the SwissMAP Junior Researcher Prize, which recognises important scientific achievements by early-career researchers in mathematics and theoretical physics in Switzerland. Supported by G-Research, the prize continues the spirit of the former SwissMAP Innovator Prize and is now carried forward within the framework of the SwissMAP Research Station.

Alessandro Giacchetto (ETH Zurich)

Alessandro is an algebraic geometer who was formerly a member of Rahul Pandharipande's group at ETH Zurich. His work lies at the intersection of enumerative geometry and mathematical physics. He studies recursive structures that govern the geometry of moduli spaces, with particular focus on cohomological field theories and their connections to integrable systems, topological recursion, and large-genus asymptotics. After completing his PhD at the Max Planck Institute for Mathematics in Bonn, he has held research positions at Paris-Saclay and ETH Zurich.

Manuel Loparco (EPFL)

Manuel studies the formalism that lies at the foundation of statistical physics, particle physics and cosmology: Quantum Field Theory (QFT). His PhD thesis was focused on QFT in the context of cosmology, studying how simple consistency conditions constrain the space of possible QFTs in an expanding universe. During the end of his PhD, he shifted his focus towards strongly coupled QFTs, which describe many phenomena of nature from phase transitions to the inner workings of a proton. His current research goal is to develop new methods to formulate predictions in these settings, where full theoretical control is still lacking. He has defended his PhD in theoretical physics at EPFL under the supervision of Joao Penedones, and is now a postdoc at Università di Torino.

RESEARCH

Previous laureates

2024	Freya Behrens (EPFL)	Samir Canning (ETH Zurich)	Romain Panis (UNIGE)

From matrices to strings

by Alessandro Giacchetto (ETH Zurich)

My research lies in enumerative geometry, especially in invariants associated with Riemann surfaces and their moduli spaces. What I find particularly compelling is that these counting problems often arise in connection with theoretical physics. Ideas from string theory, quantum field theory, and statistical physics lead to deep geometric questions, while geometry in turn provides a precise language for computing physical quantities. As an example of this interplay, I would like to describe recent joint work with R. Gopakumar and E. Mazenc, which reflects particularly well the common ground between mathematics and theoretical physics that SwissMAP seeks to foster.

A striking feature of modern theoretical physics is the existence of dualities: situations in which two very different theories describe the same physical phenomena. More precisely, two theories are physically equivalent when their *correlators*, measuring how observables interact, coincide. Gauge/string duality is one of the best-known examples.

In this work, we formulate such a duality between Hermitian matrix models and a string theory known as the B-twisted $\mathcal{N} = 2$ Landau–Ginzburg model coupled to 2d topological gravity, or LG string for short.

To explain the story, let me first recall what a Hermitian matrix model is. One considers a probability measure on the space of Hermitian $N \times N$ matrices M, defined by

$$Z_N = \int e^{-N \,\mathrm{Tr}\, V(M)}\, dM,$$

where V is a potential, for example $V(M) = \frac{M^2}{2}$, corresponding to the Gaussian Unitary Ensemble (GUE). The basic observables are traces Tr M^k. The key observation, due to 't Hooft, is that in the large-N limit their correlators organise themselves by topology:

$$\left\langle \prod_{i=1}^{n} \mathrm{Tr}\, M^{k_i} \right\rangle = \sum_{g \geq 0} N^{2-2g-n} \left\langle \prod_{i=1}^{n} \mathrm{Tr}\, M^{k_i} \right\rangle_g .$$

This strongly suggests the presence of a string theory behind the matrix model, since perturbative string theory is also organised as a sum over surfaces. The natural question is then: what is the precise string theory dual to a given matrix model?

Over the past fifty years, many special matrix models have indeed been related to string theories. A celebrated example is Witten's conjectural description of pure 2d gravity, later proved by Kontsevich. But these correspondences were usually tied to specific models, often in the double-scaling limit. One of the main points of our work is to show that this is not a collection of isolated miracles, but part of a more systematic picture.

The starting point for this picture is the geometry that emerges from a matrix model in the large-N limit. Although the model is defined as an integral over matrices, its leading behaviour is encoded by a much simpler object: the *spectral curve*. In general, this is a complex curve $\mathcal{S}$, together with two functions $x, y\colon \mathcal{S} \to \mathbb{C}$. A familiar example is the GUE, where the eigenvalues follow the Wigner semicircle law and the spectral curve is $\mathcal{S} = \mathbb{C}^*$, with $x = z + \frac{1}{z}$ and $y = z$. This is a striking instance of emergence: much as a many-particle system can be described by macroscopic quantities such as temperature and pressure, the collective behaviour of a matrix model is captured by the spectral curve.

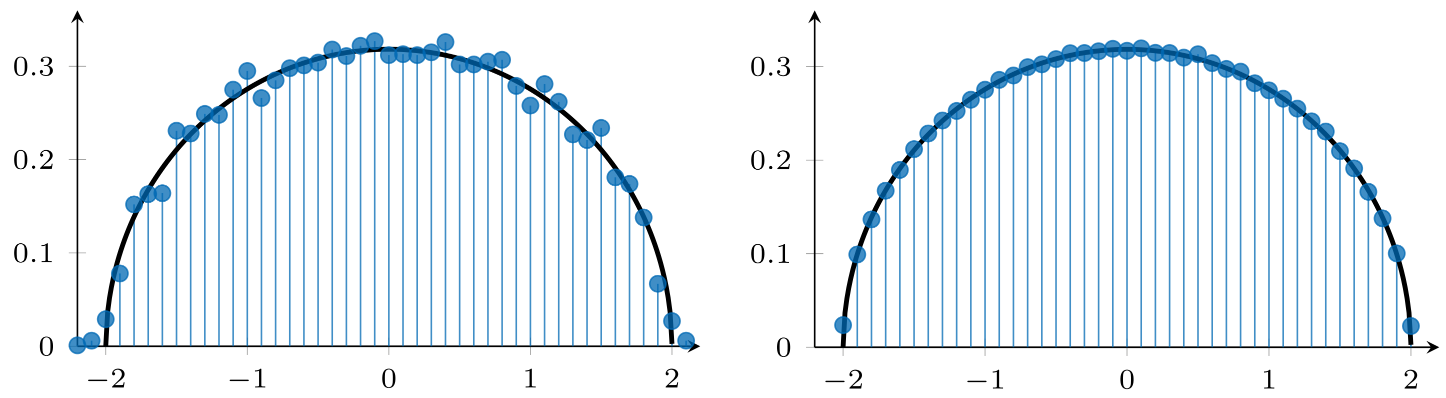


Figure 1: Eigenvalue distributions for random Hermitian matrices in the Gaussian Unitary Ensemble, for N = 20 (left) and N = 200 (right). As N grows, the empirical distribution approaches the Wigner semicircle law, illustrating how a simple large-N geometry emerges from the matrix model.

Let us now turn to the string-theory side. The dual theory is a worldsheet string theory, more precisely a Landau–Ginzburg model specified by a triple (X, W, Ω), where X is the target space, $W\colon X \to \mathbb{C}$ is a holomorphic superpotential, and Ω is a Calabi–Yau form. Before coupling to gravity, its observables form the *chiral ring*, namely holomorphic functions on X modulo the derivatives of W. Vafa showed that this defines a 2d topological field theory.

Coupling to gravity enriches this picture. Roughly speaking, it promotes the correlators from quantities attached to a fixed worldsheet to integrals over the moduli space $\overline{\mathcal{M}}_{g,n}$ of Riemann surfaces with marked points. It also introduces new observables, the *gravitational descendants*, encoded by classes ψ_i on $\overline{\mathcal{M}}_{g,n}$. The correlators therefore take the form

$$\int_{\overline{\mathcal{M}}_{g,n}} \left\langle F_1 \psi_1^{k_1} \cdots F_n \psi_n^{k_n} \right\rangle_g$$

with F_i in the chiral ring.

We can now state the correspondence. Starting from a matrix model with potential V, we construct a dual LG string whose target space is the spectral curve $\mathcal{S}$, whose superpotential is the function x, and whose Calabi–Yau form is dy:

$$X = \mathcal{S}, \qquad W = x, \qquad \Omega = dy\,.$$

So the emergent geometry of the large-N limit becomes precisely the geometric data of the dual string theory. The correspondence also provides an explicit dictionary between observables: the traces Tr M^k are mapped to explicit linear combinations of chiral elements and gravitational descendants. For instance, in the GUE case, a convenient basis of chiral elements is given by $\mathcal{O}_{\pm} = \frac{1 \pm z}{2}$, and the first few correspondences are

$$\begin{aligned}
&\mathrm{Tr}\, M \longleftrightarrow \mathcal{V}_1 = \mathcal{O}_+ + \mathcal{O}_-,\\
&\mathrm{Tr}\, M^2 \longleftrightarrow \mathcal{V}_2 = 2\mathcal{O}_+(\psi + 1) + 2\mathcal{O}_-(\psi - 1),\\
&\mathrm{Tr}\, M^3 \longleftrightarrow \mathcal{V}_3 = 6\mathcal{O}_+(\psi^2 + \psi + 1) + 6\mathcal{O}_-(\psi^2 - \psi + 1).
\end{aligned}$$

More generally, Tr M^k is mapped to an explicit linear combination of chiral elements multiplied by powers of the gravitational descendant. Putting everything together, the duality identifies the large-N correlators of the matrix model with the corresponding string correlators:

$$\left\langle \prod_{i=1}^{n} \mathrm{Tr}\, M^{k_i} \right\rangle_g = \int_{\overline{\mathcal{M}}_{g,n}} \left\langle \prod_{i=1}^{n} \mathcal{V}_{k_i} \right\rangle_g .$$

In this sense, our work makes 't Hooft's original idea concrete. Starting from a matrix potential, one extracts the emergent large-N geometry and from it constructs the dual worldsheet theory together with an explicit dictionary between matrix and string observables.

The two sides of the correspondence have very different mathematical natures, and this makes the duality especially fruitful. For example, in the GUE, trace correlators are positive integers because they count Wick contractions. The duality therefore implies that the corresponding moduli-space integrals are positive integers as well, which is far from obvious from the geometric side alone.

More broadly, this is the kind of interaction that drives much of my research in enumerative geometry: counting problems on moduli spaces acquire deeper meaning through physics, while physical dualities become more precise when translated into geometric language.

Quantum Field Theory as a set of ODEs

by Manuel Loparco (EPFL)

Many phenomena of nature are described by *field theories*. Gravity, particle physics, statistical physics, cosmology, and hydrodynamics are all best described by models in which the essential ingredients are fields. Some of these field theories are weakly interacting, meaning that field excitations mostly pass through each other and only rarely interact. An example is quantum electrodynamics, the field theory of electromagnetic phenomena. In it, photons and electrons — the particle excitations of the underlying fields — travel through space mostly unbothered until they meet and interact briefly.

Most field theories, however, are strongly coupled. A famous example is quantum chromodynamics, in which the field excitations are the quarks and gluons that constitute protons and neutrons. Quarks and gluons do not travel freely; rather, they are "confined", binding to one another to form hadrons (including mesons, baryons, and a vast zoo of short-lived particles). This makes them significantly more difficult to treat than photons and electrons.

Strongly coupled field theories are truly ubiquitous. They arise as models of phase transitions between various states of matter, as well as near-critical phenomena where the microscopic details of a system give way to universal collective behaviors.

Given the vastity of phenomena described by strongly coupled field theories, understanding how to formulate predictions in these models would have applications across many branches of physics. Unfortunately, to this day, most progress has been made in understanding their weakly coupled counterparts. It is through this progress that we can, for example, compute the anomalous magnetic moment of the electron and compare it to experiments with the astonishing precision of one part in a billion.

For strongly coupled field theories, we possess only a few expensive computational tools. The most successful is the lattice approach, in which spacetime is discretized and modeled by a lattice of points. In this picture, fields take values on the nodes and links of the lattice: typically, the matter fields live on the nodes, while the force-carrying fields are associated with the links. This discretization procedure makes the system solvable even at strong coupling, but at the expense of having to simulate a huge number of sites to achieve acceptable accuracy. With this approach, researchers were able to compute the mass of the proton as it arises from the interactions of quarks and gluons with an accuracy of 1%.

Most of my research efforts are now focused on a new method to attack strongly coupled field theories, which we first proposed in [1]. The core idea is to temporarily imagine that our field theory of interest lives on a background geometry with constant negative curvature (eventually, we will bring this curvature back to zero). In physics, such a geometry is called an Anti-de Sitter (AdS) space. The advantage is that field theories in AdS geometries have a remarkably simple emergent description due to the peculiar symmetries of this space. Concretely, the geometry of AdS ensures that the outcome of every possible local measurement is fixed by three lists of ingredients (which we call the QFT data), which depend on the coupling of the theory in units of the curvature of AdS, λ:

- $\Delta_i(\lambda)$: The energy spectrum of the theory, which the geometry of AdS forces to be discrete
- $C_{ijk}(\lambda)$: The structure constants, quantifying how similar the product of two states *i* and *j* is to state *k*.
- $b_i^{\hat{\Phi}}(\lambda)$: The spectral density of the interaction $\hat{\Phi}$ — or how this interaction term decomposes into energy eigenstates.

Field theories in AdS are thus "solved" if we know the QFT data, because any (local) observable property of the system can be reconstructed starting from it. What we did in [1] was to derive a set of coupled ordinary differential equations (ODEs) that govern the evolution of the QFT data as we change λ.

If we start from a solvable, weakly coupled field theory at $\lambda = 0$, we can derive the initial conditions for these functions. Then, by numerically solving the ODEs, one can increase λ and enter a strongly coupled regime. Taking $\lambda \to \infty$ effectively corresponds to taking the curvature of AdS to zero, restoring the "flat" geometry that is appropriate to model a laboratory setting. All in all, one can in principle extract information about the spectrum and the scattering matrix of a strongly coupled field theory on a regular "flat" geometry from the asymptotic solutions of these ODEs.

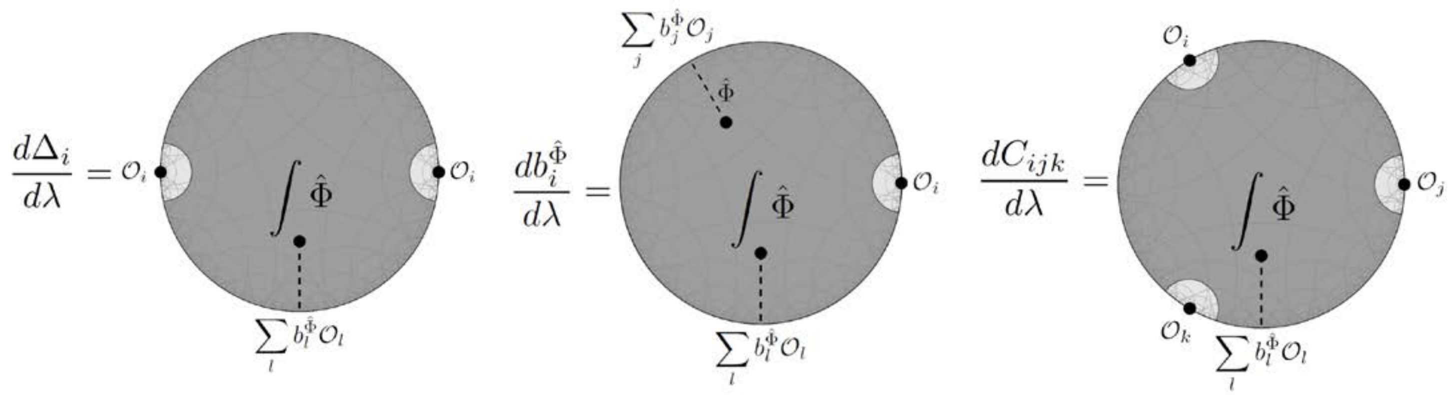


Figure 1: A pictorial representation of the ODEs governing the flow of the QFT data

This research program is in its infancy. We have just derived the relevant ODEs for a two-dimensional geometry and verified them in a non-interacting theory. It was a long and complicated process, but with the experience gathered, we are now making quick progress in generalising them to higher dimensions. In parallel, we are exploring the first applications in two dimensions. Although we have good arguments to believe the framework should work generally, optimism should be cautious until we manage to use this method to extract observables in a genuine strongly coupled field theory. Nevertheless, one cannot help but be excited at the prospect that solving a strongly coupled field theory might be as simple — or as hard — as solving a set of coupled ODEs. This structure would endow field theory with a beautifully simple mathematical basis. The study of these ODEs and the curves that solve them, their non-trivial consistency constraints, and their behavior under deformations are all compelling research questions that naturally arise. By reframing the hardest problems of field theory as questions of classical analysis, we may find a new systematic path through the landscape of strong interactions.

[1]: M. Loparco, G. Mathys, J. Penedones, J. Qiao, X. Zhao, "QFT as a set of ODEs", arXiv:2601.04310

SRS Calendar

SRS SwissMAP Research Station in Les Diablerets

Scientific Program 2026

WINTER SCHOOL IN MATHEMATICAL PHYSICS
January 4-9
A. Alekseev (UNIGE), A. Cattaneo (UZH), G. Felder (ETH Zurich), M. Podkopaeva (IHES), E. Raphael (UNIGE), T. Strobl (U. Lyon 1), A. Szenes (UNIGE)

TURBULENCE & MIXING IN FLUID DYNAMICS
January 11-16
M. Colombo (EPF Lausanne), G. Crippa (UNIBAS), K. Widmayer (UZH)

HOMOLOGICAL, QUANTUM, AND COMPUTATIONAL METHODS IN LOW-DIMENSIONAL TOPOLOGY
January 18-23
A. Alekseev (UNIGE), Z. Dancso (U. Sydney), I. Halacheva (Northeastern U.)

QUANTUM CORRELATIONS AND MEASUREMENTS
February 1-6
N. Brunner (UNIGE), P. Sekatski (UNIGE), R. Uola (UNIGE), M. Wilenmann (UNIGE)

WORKSHOP IN MATHEMATICAL PHYSICS 2026
February 8-13
R. Mahfouf (UNIGE), S. Smirnov (UNIGE)

LES MARMOTTES
April 13-17
S. Moody (Collège de Genève), E. Raphael (UNIGE)

MODULI OF CURVES AND ABELIAN VARIETIES
May 3-8
S. Canning (ETH Zurich), R. Pandharipande (ETH Zurich), J. Schmitt (ETH Zurich)

SUMMER ACADEMY OF THE JUNIOR EULER SOCIETY
May 13-17
T. Samrowski (UZH)

ADVANCED LECTURES IN PHYSICS IN SWITZERLAND III
May 17-22
R. Baumgartner (UNIGE), A. Florio (Brookhaven Nat. Lab.), S. Murciano (Caltech), V. Pellizzani (UNIBE)

COMPUTATIONAL OPTIMIZATION MEETS GRADIENT FLOWS & OPTIMAL TRANSPORT
May 24-29
N. He (ETH Zurich), Y. Hu (EPF Lausanne), D. Kuhn (EPF Lausanne), J-J. Zhu (WIAS Berlin)

MODULI SPACES AND GRAPH COMPLEXES IN ALGEBRA, GEOMETRY & PHYSICS
May 31 - June 5
M. Borinsky (ETH Zurich), S. Payne (UT at Austin), K. Vogtmann (U. Warwick), T. Willwacher (ETH Zurich)

SHUFFLE ALGEBRAS AND QUANTUM LOOP GROUPS
June 7-12
A. Negut (EPFL), J. Wen (U. Vienna)

GROUPS AND OPERATOR ALGEBRAS
June 14-19
M. Caspers (TU Delft), S. Geffen (U. Münster), A. Skalski (IMPAN), A. Valette (UNINE)

NEW DIRECTIONS IN THE LARGE-CHARGE EXPANSION
June 21-26
S. Beane (U. of Washington), D. Orlando (INFN), S. Reffert (UNIBE)

EULER CAMP SUMMER SCHOOL
June 29 - July 3
J. Scherer (EPF Lausanne)

REGULARITY THEORY FOR EVOLUTION EQUATIONS
July 5-10
M. Iacobelli (ETH Zurich), A. Loher (U. Cambridge), C. Mouhot (U. Cambridge), A. Rebucci (MPI Leipzig)

MAPSS 2026
July 12-24
A. Alekseev (UNIGE), N. Nikolaev (U. Birmingham), E. Raphael (UNIGE)

QUANTUM KEY DISTRIBUTION SUMMER SCHOOL
August 16-21
C. Ferradini (ETH Zurich), R. Renner (ETH Zurich), M. Sandfuchs (ETH Zurich), R. Wolf (ETH Zurich)

MODULI SPACES, QUANTIZATION AND POISSON GEOMETRY
August 23-28
A. Alekseev (UNIGE), H. Bursztyn (IMPA), D. Krepski (U. Manitoba), Y. Loizides (George Mason U.)

ELLIPTICS & BEYOND '26
September 6-11
K. Baune (ETH Zurich), J. Broedel (ETH Zurich), F. Zerbini (UNED, Madrid)

CONTEMPORARY TRENDS IN HAMILTONIAN GEOMETRY
September 27 - October 2
A. Alekseev (UNIGE), A. Cannas da Silva (ETH Zurich), R. Chiang (NCKU), L. Kessler (U. Haifa), J. Palmer (Amherst College), D. Sepe (U. Medellin)

GEOCOW: GEOMETRY OF COMPLEX WEBS
November 1-6
R. Delabays (HES-SO), M. Jacquemet (HES-SO & UNIFR), C. Mazza (UNIFR), E. Raphael (UNIGE)

SRS SwissMAP Research Station in Les Diablerets

Scientific Program 2027

WINTER SCHOOL IN MATHEMATICAL PHYSICS
January 10-15
A. Alekseev (UNIGE), A. Cattaneo (UZH), G. Felder (ETH Zurich), M. Podkopaeva (IHES), E. Raphael (UNIGE), T. Strobl (U. Lyon 1), A. Szenes (UNIGE)

THE DYNAMICS OF INFORMATION IN NEURAL NETWORKS: FROM INTERACTING PARTICLES TO CONTINUUM FLOWS
January 17-22
A. Agazzi (UNIBE), B. Geshkovski (INRIA Paris), P. Rigollet (MIT)

STOCHASTIC ANALYSIS AT LES DIABLERETS
January 24-29
M. Gubinelli (U. of Oxford), X.-M. Li (EPF Lausanne)

UNIVERSAL GEOMETRIC AND ALGEBRAIC STRUCTURES IN QUANTUM AND GRAVITATIONAL PHYSICS
January 31 - February 5
S. Shatashvili (Trinity College), J. Sonner (UNIGE), E. Verlinde (U. of Amsterdam)

WORKSHOP IN MATHEMATICAL PHYSICS 2027
February 14-19
S. Smirnov (UNIGE)

INTERNATIONAL EGMO CAMP
February 21-26
T. Samrowski (UZH), K. Slavov (ETH Zurich)

COMBINATORICS: TOOLS AND APPLICATIONS
February 28 - March 5
A. Shapira (Tel Aviv U.), B. Sudakov (ETH Zurich)

LES MARMOTTES
March 29 - April 3
S. Moody (Collège de Genève), E. Raphael (UNIGE)

SUMMER ACADEMY OF THE JUNIOR EULER SOCIETY
May 5-9
T. Samrowski (UZH)

ENUMERATIVE GEOMETRY IN SCATTERING DIAGRAMS
May 9-14
M. van Garrel (U. of Birmingham), C. Manolache (U. of Sheffield), H. Ruddat (U. of Stavanger)

SINGULARITIES, SOLITONS, AND STABILITY IN GENERAL RELATIVITY
May 16-21
I. Kadar (ETH Zurich), C. Kehle (MIT, UZH), L. Kehrberger (MPI Leipzig, Leipzig U.), B. Schörkhuber (Innsbruck U.)

ADVANCED LECTURES IN PHYSICS IN SWITZERLAND IV
May 23-28
R. Baumgartner (UNIGE), A. Florio (U. of Bielefeld), S. Murciano (Paris Saclay), V. Pellizzani (U. of Oxford)

THE HELVETIC ALGEBRAIC GEOMETRY SEMINAR (HAGS) 2027
May 30 - June 4
R. Pandharipande (ETH Zurich), A. Szenes (UNIGE), R. Thomas (ICL)

EUROPEAN KYLEREC
June 6-11
G. Bargallo i Gomez (Humboldt U.), A. Hirshi (Sorbonne U.), K. Hugtenburg (St. Andrews), F. Strakos (Uppsala U.), T. Poppe (NTNU)

PHASES OF OPEN QUANTUM SYSTEMS: COMPLEXITY, LEARNABILITY
June 13-18
S. Gopalakrishnan (Princeton U.), R. Vasseur (UNIGE), C. Zhang (Harvard U.)

FJSM CAMP
July 2-4
E. Cantoni (FJSM), Noé Curtz (FJSM), Jean-Claude Favre (FJSM)

RICCI FLOWS, SUPERGRAVITY, AND COURANT ALGEBROIDS
July 4-9
M. Gualtieri (U. of Toronto), P. Severa (UNIGE), F. Valach (Charles U.)

MAPSS 2027
July 16-25
A. Alekseev (UNIGE), N. Nikolaev (U. of Birmingham), E. Raphael (UNIGE)

LIE THEORY, POISSON GEOMETRY, AND THEIR APPLICATIONS IN PHYSICS
August 15-20
Y. Li (SCU), L. Parnovski (UCL), M. Podkopaeva (IHES), E. Raphael (UNIGE)

ALPINE ALGEBRAIC AND APPLIED TOPOLOGY CONFERENCE 2027
August 22-27
D. Egas (MPI-CBG, CSBD), B. Johnson (Union College), K. Maggs (MPI-CBG), L. Moser (U. Regensburg), N. Rasekh (U. Greifswald), M. Rovelli (U. of Ottawa, UMass Amherst), J. Scherer (EPF Lausanne), M. Stephan (MPI-CBG, TU Dresden)

GRAPH INTEGRALS IN MATHEMATICS AND PHYSICS
August 29 - September 3
D. Calaque (U. of Montpellier), C. Dupont (U. of Montpellier), E. Panzer (U. of Oxford)

SRS Timeline

Winter

→ **Publication of the program for the year N+1**

→ **Winter School and SwissMAP Junior Researcher Prize ceremony**

Spring

→ **MAPSS registration opening**

→ **Call for applications for the SwissMAP Junior Researcher Prize - open**

Summer

→ **MAPSS Summer School**
Mathematical Physics Summer School

→ **Call for proposals to organise a conference at the SRS - open**

Autumn

→ **Winter School registration opening**

→ **Call for applications for the SwissMAP Junior Researcher Prize - close**
15 September 2026

→ **Call for proposals to organise a conference at the SRS - close**
10 October 2026

Subscribe to our SRS mailing list to keep up to date with calls and announcements.

Videos

We aim to share our events' scientific content with as wide an audience as possible online.

You can find the following videos on the NCCR SwissMAP YouTube Channel – SRS playlist

2025

- International Workshop on Automorphic Forms (Aug 31 – Sept 5)
- Intersections of Topological Recursion, Conformal Field Theory, and Random Geometry (Aug 24 – Aug 29)
- The Amplituhedron: Structure, Combinatorics, and Positive Geometry (Jun 29 – Jul 4).
- 2025 SCGCS School – Topological Symmetries and Defects in Quantum Field Theory (Jun 15 – Jun 20)
- Polylogarithms, homology of linear groups, and Steinberg modules (Jun 8 – Jun 13)
- Effective theories for many-body systems out of equilibrium (May 11 – May 16)

2024

- Quantum Key Distribution Summer School (August 18 – August 23)
- Mathematical Physics Summer School (July 14 – July 19)
- Les Marmottes – Filles et Maths (Apr 8 – Apr 12)
- Conformal field theory 3 ways: integrable, probabilistic, and supersymmetric (Jan 21 – Jan 26)
- Quantum Topology Biennial (QTB): focus on representation theory (Jan 14 – Jan 19)

2023

- Quantisation of moduli spaces from different perspectives (Sept 24 – Sept 29)
- Categorical Symmetries in Quantum Field Theory (Conference and School) (Aug 27 – Sept 8)
- Effective theories in classical and quantum particle systems (June 18 – June 23)
- Finite dimensional integrability in mathematical physics (June 11 – June 16)
- Analytic techniques in Dynamics and Geometry (May 28 – June 2)
- Geometric and analytic aspects of the Quantum Hall effect (May 7 – May 12)
- Integrability in Condensed Matter Physics and Quantum Field Theory (Feb 3 – Feb 12)

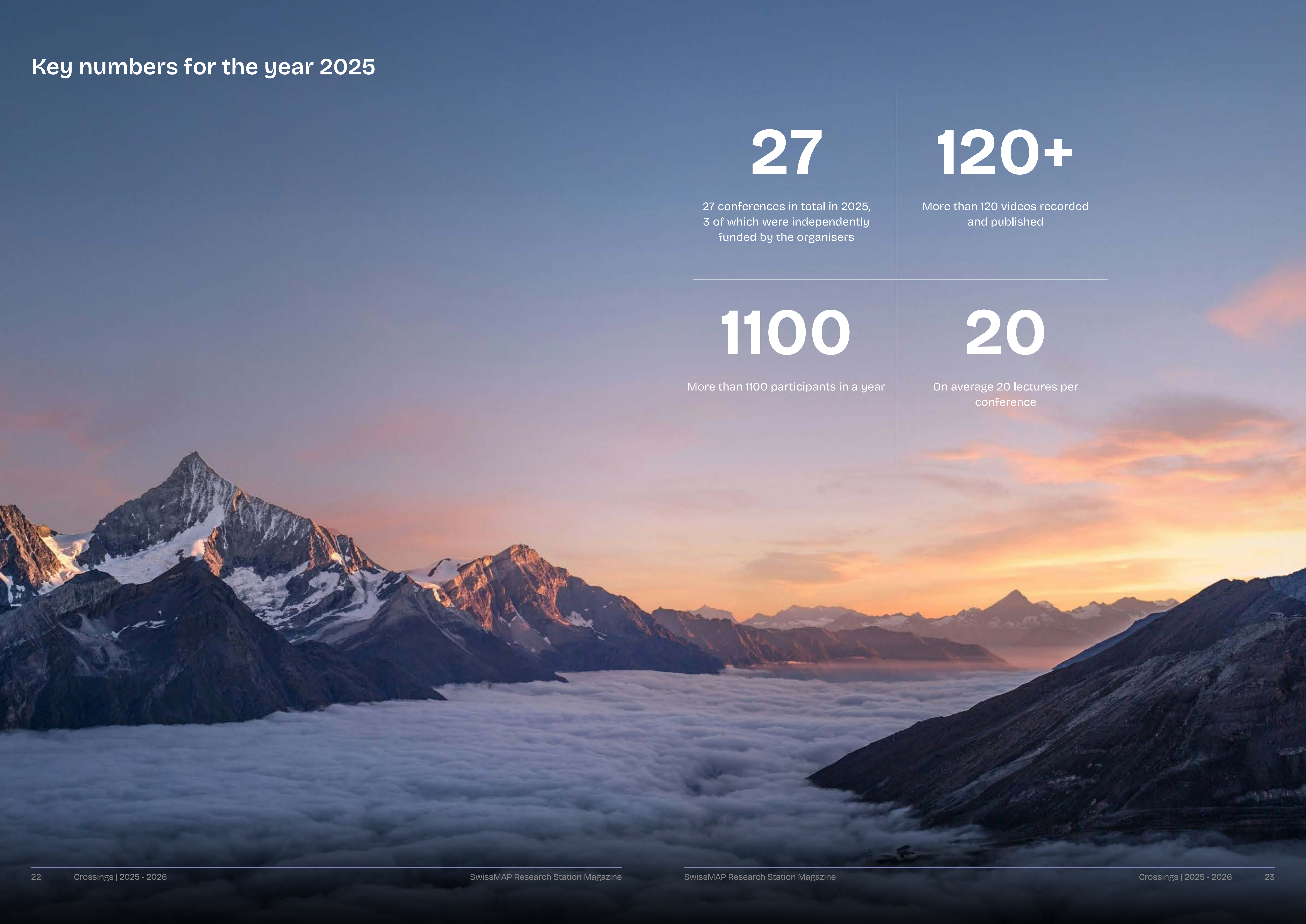
2022

- Climathics (Nov 28 – Dec 2)
- Let's talk about outreach! (Oct 23 – Oct 29)
- Workshop on Spin Glasses (Sept 25 – Sept 30)
- Young Group Theorists Workshop: exploring new connections (Sept 4 – Sept 9)
- Algebra, Topology and the Grothendieck-Teichmüller group (Aug 28 – Sept 2)
- Gauged Maps Vortices and Their Moduli (Aug 21 – Aug 26)
- Deciphering AdS/CFT (Apr 10 – Apr 15)
- Vertex Algebras & Poisson Geometry (Feb 20 – Feb 25)
- Differentiable Stacks, Poisson Geometry and related geometric structures (Feb 6 – Feb 11)
- Recent development in Link Homology (Jan 30 – Feb 4)
- From Coadjoint Orbits to Black Holes (Jan 16 – Jan 21)
- Winter School in Mathematical Physics 2022 (Jan 9 – Jan 14)

2021

- Emergent Theories for Wave Turbulence and Particle Dynamics (June 21 – June 25)
- Geometry, Topology and Physics in Les Diablerets (June 13 – June 18)
- Cohomology of moduli spaces of flat connections (Jan 31 – Feb 4)
- Winter School in Mathematical Physics 2021 (Jan 20 – Jan 22)
- Launch of the SwissMAP Research Station

Key numbers for the year 2025



27

27 conferences in total in 2025, 3 of which were independently funded by the organisers

120+

More than 120 videos recorded and published

1100

More than 1100 participants in a year

20

On average 20 lectures per conference

For further information please contact:
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Les Diablerets

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