SwissMAP
The Mathematics of Physics
National Centre of Competence in Research

SwissMAP Perspectives

Issue 10 | 2025

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SRS² Initiative

The SRS² program (Short Reseach Stays at the SwissMAP Research Station) aims at enabling small groups of researchers (2-6 people) to work on specific projects for a short period (1-3 weeks) within the SwissMAP Research Station facilities in Les Diablerets.
In this interview, Edward Mazenc (ETH Zurich, M. Gaberdiel's Group) shares his experience as an organizer of an SRS² workshop.

What makes the SwissMAP Research Station in Les Diablerets particularly well suited for an initiative like SRS²?

The SRS² workshops are tailor-made to break open new research directions. That means exploring new territory, where the rules of the game are still unclear. Making progress requires a lot of time face-to-face, brainstorming together at the board, and working as a team to continuously course-correct the path forward. The SwissMAP Research Station provides that type of close-knit environment, where some of the daily distractions of academic life can be put on hold and some real group momentum can be built up. On top of that, remote collaborations later work best when one knows the team not just as collaborators, but as people and friends. The shared daily meals and long discussions over scenic hikes are fantastic catalysts in that regard.

Your project brought together six researchers from ETH, MIT, Queen Mary, and CERN. Could you tell us how this collaborative initiative first came about? Had you already been working together, for instance through previous or ongoing joint papers, or was this a completely new collaboration? How did the group come together, and what were the initial goals?

While many of the participants knew some of the other researchers already, it was a brand new collaboration as a whole. We brought together scientists who seemed to all be stumbling upon various manifestations of the same underlying idea. Some were experts in holography, and the prototypical particle-physics-like theory often studied in that context (N=4 Super Yang-Mills theory), while others were coming from the intersection of quantum information and condensed matter theory.

> Making progress requires a lot of time face-to-face, brainstorming together at the board, and working as a team to continuously course-correct the path forward.

The working group focused on open/closed/open triality, a relatively recent concept at the intersection of mathematical physics and string theory. Could you briefly explain this idea in simple terms, and why it was particularly well suited to an intensive format like SRS²?

One of the most startling discoveries in theoretical physics of the past few decades has arguably been the idea that large N gauge theories (of the type we use to describe particle physics, and which we understand well) are equivalent to certain theories of quantum gravity (which we don't understand well). From the point of view of string theory, what underlies this equivalence is a duality between open and closed strings, respectively. You can think of open strings as little segments of string, with two endpoints. Closed strings, on the other hand, are "circular," and don't have endpoints. As strings evolve in time, they sweep out a two-dimensional surface in spacetime, known as the "worldsheet" of the string. Open string worldsheets have holes in them, whose boundaries are traced out by their endpoints. From the point of view of the gauge theory, these worldsheets are Feynman diagrams, certain graphs that we use to compute things in these particle-physics-like theories. On the other hand, closed strings are Riemann surfaces without holes. One crude way of deciphering open/closed duality is to figure out a canonical way to "shrink" the holes of open string worldsheets to obtain the worldsheets of the closed ones. Open/Closed/Open triality, pioneered by Rajesh Gopakumar, started with the observation that there were in fact two canonical ways in which these holes shrink away. But it goes further—it states that there are generically two different open string theories equivalent to a closed one, each one relying on one of the two distinct mechanisms as to how these boundaries are shrunk down. One of the amazing predictions of Open/Closed/Open triality is that the Feynman diagrams of the two open descriptions can be individually mapped onto each other via graph duality (exchanging vertices and faces of these graphs). It was this prediction which had been observed in various circumstances, in fields as far as the classification of certain 2D materials in condensed matter theory, and whose significance we are just now beginning to appreciate.

As it can be very hard to understand how and why a certain phenomenon appears in seemingly unrelated physical setups, it was crucial to have experts from each topic to be able to explain and communicate this result to the rest of us. In the standard university setting, we often only get a quick seminar from a visiting speaker and don't have the time to ask all the questions necessary to truly understand a result. In our workshop, each speaker had several hours to explain the relevant background, and create a common vocabulary for us to usefully exchange ideas across our respective fields of expertise.

In which direction did you make the most progress and why?

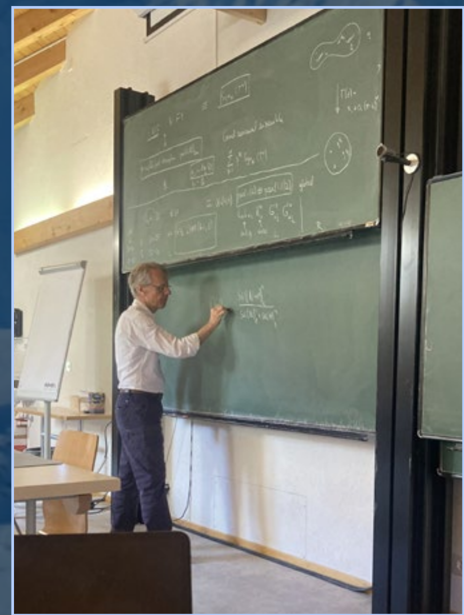
Our main goal was honestly a mission of demystification—can we understand the common origins of the various manifestations of this idea. We then wanted to use the commonalities to pinpoint what is important and general about Open/Closed/Open triality, and trim down those aspects that are likely artefacts of the particular examples we have studied so far. In that regard, it was a great success.

Looking ahead, how do you anticipate continuing or building upon the collaborations and ideas developed during this meeting? Are there specific next steps your group plans to take?

We subsequently managed to find an instantiation of Open/Closed/Open triality lurking in a topological subsector of the much-studied N=4 Super Yang-Mills theory I mentioned previously. This was an important step to elevate this new idea beyond the toy model string theories where it had been discovered. We are already at work to further generalize this result to "half" of this N=4 Super Yang-Mills theory (its so-called "chiral algebra"). To be honest, we are just at the beginning of fleshing out what Open/Closed/Open triality really means: it's an exciting time!

Finally, what advice would you give to people participating in such a week in order to maximize the impact of their research?

While the format is very intense, our week in Les Diablerets flew by! I think it was important that we had set up a common reading list beforehand, so that we all began the week on the same page. For us, each participant had prepared a mini set of lectures, with plenty of room for questions, and this really created the common ground for fruitful conversations. In short, some preliminary preparation to ensure a shared knowledge toolkit goes a long way towards a productive research stay!



Interview of Edward Mazenc
(M. Gaberdiel's Group)
ETH Zurich

A conversation with Julian Sonner

Julian Sonner is a professor of theoretical physics at the University of Geneva. He spent three years as a postdoc at MIT, before joining the faculty at the University of Geneva.

Julian is interested in string theory, holography and condensed matter physics and their mutual interactions. A favorite example involves the formation and subsequent evolution of black holes and how these notions have their counterparts in the study of thermalization in quantum many-body systems.

When and how did you get interested in physics?

My interest in physics started very early on during my childhood, and continued throughout my childhood and adolescence. I wasn't pursuing it as a possible career, as I was more interested in pursuing music at the time, but it was still something that interested me a lot. I remember when I was around 8 years old, my parents got me a library card at the local library, and I just naturally gravitated towards books that were about science. I always brought loads of these books home to read, and apparently, I also made a point of explaining the things I read to people around me, which I gather may have been a bit annoying. So, the fascination had always been there.

And in my case, this interest was more self-driven, because my parents are not at all scientists, they are actually authors. My father is a novelist, and my mother does mostly journalistic writing in the fields of theatre, music and art, and both have a history of political activism. So, my interest in science did not come from encouragement from my family, but was really a passion I developed on my own. I grew up in Munich , a city that has a fantastic science museum, with a great library as well that was publicly accessible. I used to go there and treasure the books I would find and take them home to read. Of course, most of the time I didn't understand them as they were already quite advanced-level books. But I always thought of it as this deep intellectual pursuit that I found extremely fascinating.

For most of my childhood however, I invested a lot of my time and effort into pursuing a career in music, I had the goal of becoming a concert pianist, or perhaps an orchestral conductor. It was only much later, that I came to think that maybe science was what I truly want to do. And it was still through books that this passion of mine for science had developed. As a teenager, I started to understand certain concepts better, and I remember two particular books that were quite striking for me when I was about 14 years old. One was a book by a German physicist Harald Fritzsch who was a pioneer of the theory of QCD, the theory of strong interactions quite early on in its development. He also wrote popular science books on elementary particle physics in general, and it was his book "Elementarteilchen" which I remember. The second book I remember having influenced me was by Michio Kaku, who nowadays has a slightly dubious reputation among scientists about how good the quality of his outreach really is. But back then I enjoyed his book a lot. It was about all the modern ideas in gravity, string theory, extra dimensions and so on. These two books also oriented me closer to the research directions I eventually chose to focus on.

How and why did you choose the academic path?

That path always seemed a natural choice for me. Even though my parents weren't academics and didn't work at the University, this type of intellectual pursuit was still something highly valued in my family and among our family friends. So, this was a clear path if you wanted to go in the direction of research or any other serious scholarly endeavour. It was also clearly a direction that was highly respected. This is where my surroundings had a beneficial influence, as it made it easy for me to see academia as a possible career path. Some people do it despite their surroundings, but it was quite the opposite for me. Nevertheless, the topics I chose were to some extent rebellious as there were no scientists in our family, and my family was always very vocally convinced of their choices in life. They believed that it would be much more valuable to be an artist or pursue some other creative venture. Nowadays, their view has changed somewhat, as they have realized that there is a great deal of creativity in what we as scientists do as well. There is a great deal of exploring and creating new things.

> There is a great deal of creativity in what we as scientists do... a great deal of exploring and creating new things.

What are you working on right now?

I have fairly broad interests, but I can pinpoint three directions that I'm very involved in. They range from what is essentially mathematical physics, to something that is directly connected to experiments.

The first one concerns a very new idea on how we should think about the gravitational path integral, and in particular in lower dimensions. By "lower dimensions" we mean lower than the ones we observe around us, so that would be four dimensions. We have now worked our way up to three dimensions, so we're almost where we want to be. There's a way that basically constructs the path integral for three-dimensional gravity, but starting from a seemingly different point of view namely, by looking at chaos in conformal field theory (CFT). CFT's are special quantum mechanical systems – quantum field theories, which possess a high degree of symmetry. We basically came up with a way of describing such theories in an average way, and they show a strong form of chaos (in the mathematical sense). To our great surprise, out of this came what looks like a description of the 3D path integral. So this is something we are pursuing, and other groups in the world are also working on it these days. It's a very active topic.

The second one is more in the tradition of theoretical physics. For many years now, with a range of collaborators including PhD students in Geneva, we have been formulating and exploring a notion of what is known as quantum complexity. And quantum complexity is actually also related to the notion of chaos. If you wanted to realise a physical state, let's say in a given quantum system explicitly, how difficult would it be? Of course we end up formulating this measure of difficulty mathematically, but you can still keep this intuitive notion in mind of how many resources you would need to prepare a given quantum state. For example, how big of a quantum computer would you have to build in order to realise such a state? A particular notion that we are pursuing, is called "Krylov complexity", named after the Russian/Soviet engineer Alexey Krylov, who is quite a fascinating figure by the way. This Krylov complexity is a notion of how difficult it is to reach a certain state, or construct a certain observable, in quantum mechanics. We have recently finished a very long review of this subject and, as far as I know, it's the most mathematically well-defined notion of quantum complexity that moreover seems to have many applications in gravity, many-body physics, quantum information and more. It is a very active field and we're strongly pursuing it. Perhaps I should add that my former PhD student Adrián Sánchez-Garrido has been awarded the SwissMAP innovator prize for his thesis on Krylov complexity.

And finally, the third one, is about the ways of understanding quantum gravity, its phenomenology and its mathematical formulation in terms of holographic dualities. I believe many people have heard of them by now. Many scientists around the world are working on this from a theoretical point of view, but what has not yet been done, is to see whether one could make a direct connection to experiments. So, we have come up with ideas and proposals on how to realise the field-theory side of this in real laboratory settings and in particular, using quantum simulations of what we call synthetic holographic matter. In some sense these models would show an emergent collective behaviour that is best described by associating to it the physics and phenomenology of quantum gravity. And this work has really come quite far. In fact, initially it was only supported by SwissMAP and no other funding sources wanted to support it. But now, we have a lot more support from other sources, as well as direct support for the part which involves experimental labs at EPFL and ETHZ. These labs are doing experiments according to the ideas that we as theorists developed, though of course the really hard bit is to actually make such experiments work in practice. It is now a great back and forth between theory and experiment, and I

Julian Sonner at the SwissMAP General Meeting in 2022. Credit: Julien Photographe

believe it holds great promise. Maybe within the next few years, we'll actually see the first experimental realisation of these holographic dualities.

What exciting things are happening in your field at the moment?

One of the things that has convinced me personally to look more into these fundamental issues in quantum gravity, is that other scientists in recent years have made really important progress on some old puzzles that were around since before I started my PhD, in fact since the 1960s and 1970s. I was very much aware of these problems as a PhD student and they seemed very far away and beyond the grasp of ever being solved. And while they're not solved fully today either, for example a full microscopic understanding is still missing, there is still spectacular progress being made in this field. In particular, there has been a lot of progress in elucidating the information loss puzzle raised by Steven Hawking who was still very present in Cambridge when I was a PhD student at his chair and naturally, it was discussed a lot back then. At the time, it seemed like everything interesting that could be said had already been said, and finding a solution would be essentially impossible with the methods that we had. But in fact, surprisingly the methods that contemporary approaches apply successfully, are actually very close to the methods that Hawking had outlined in his original papers and that he was telling us about back in Cambridge. These closely related new approaches eluded even him at the time, but nevertheless great progress has been made recently.

Another field that has had some spectacular developments and has also influenced my own work in an indirect way, is quantum technology. The effort to build real quantum computers, at the research level, has led to such an amazing growth of experimental ways to control quantum matter and quantum many-body states. What is now experimentally possible, would have been unimaginable even at the time of my PhD. Back then, there were some people who told me, that to have a big impact, I should do my PhD in this field. But I ignored them, partly because I didn't find the specific problems that interesting, and also because I didn't see the great potential at the time. But I believe, it has been the field with the most spectacular progress in physics in the last decade or so.

Finally, it's also a good idea to keep an eye on what's happening with AI and the developments around neural nets and large language models; and the even more innovative ways of making computers do tasks that make them seem really intelligent in a way that, again, five years ago, we thought would be impossible. It's also spectacular to see what's going on in that field too.

What have been the most rewarding or favourite moments in your career so far?

For me, the rewarding part of science is when you find something you didn't expect. Of course, it's also rewarding to solve a well-defined but hard problem that you know will be important progress. But when you set a goal, let's say to establish something to be true, and then you realise it cannot be established because maybe the hypothesis is wrong or perhaps for some other reason, but instead something entirely different comes out of it, that is even more interesting.

This has happened to me a few times. I started my PhD working on a fundamental aspects of gravity, but then I went into more applied directions. We started applying the methods we learned in black-hole physics to many-body systems. And we realised that some of the models that we created, showed behaviour for example in the form of phase diagrams, that are very similar to superconducts, in fact un-conventional superconductors. We didn't design it to be the case; we worked out what the phase diagram is and it just worked beautifully. And this was an unexpected but rewarding discovery.

A more recent example, was when we got a theory of three-dimensional gravity, even though our starting point had nothing to do with it. We started with the idea of wanting to describe what would happen if you average over chaotic CFT's. And to our great surprise, what came out of this was a model that describes three-manifolds and some average or sum over three-manifolds, that we are convinced is probably a theory of 3d quantum gravity. We absolutely did not design or even expect that, and so it was a total surprise. It's these moments where the research is telling you what to do and what is correct, and I find that very rewarding.

What have been the greatest challenges you had to face?

I believe that in my case, I have found that the biggest challenges in my life have been more of a personal nature that perhaps I won't go into in this format. But it does illustrate that sometimes, maybe by luck or some other reason, academic careers can go relatively smoothly. Sometimes, you have more challenges in your personal life than you have in your professional life. And although it has not been the case for me, personal challenges can sometimes negatively impact your research and your professional career, so they are not totally disjoint.

But one challenge I faced in research was at the beginning of my PhD. The first year or so, my PhD was very exhausting and mentally difficult. I was not making that much progress even though I was working extremely hard, basically too hard. And at some point, I reached a stage where I realised, I had to take time off, instead of trying to break through a wall that I had already run against a hundred times and bounced back off every time. The key moment was that after only a few weeks of time off, the solution just sort of came to me, without me actually thinking about the problem. The takeaway is that it's easy to work yourself into the ground by thinking that putting more effort into the problem will give you the solution. For me, that's not the right way of getting a result. And in response to that, I also somewhat changed my approach. To develop as an academic, I had to find early on my own language to talk about physics, and my own direction to pursue. I could never really tolerate being told what to do. And if I had submitted myself to always doing what other people tell me, I might've burnt out fairly quickly, because it's hard to find the motivation for me that way.

A more recent challenge for me, is to reconcile my work with having a family and being a father. I think most of us value our work greatly as it's a work of passion. So, it is easy to carry the work into our home and to always be thinking about the problems we're trying to solve and not being present when we're with our families. I find this challenging every day, but I try my best. There is also the issue of having less time if you have both a family and work obligations. I don't want my work obligations to impact my family as I find it not right towards them and that is always a challenge with feelings of guilt and responsibility.

For me, the rewarding part of science is when you find something you didn't expect. When you set a goal, but instead something entirely different comes out of it. These moments where the research is telling you what to do and what is correct.

What advice would you give to a PhD student who wants to pursue an academic career?

This is probably somewhat idealistic advice, but it's one I got myself and I think it's spot on. If you want to have an academic career, you have to work on what you're passionate about. You have to want to do the work because it is your passion and then work very hard. Doing a nine-to-five job, and just showing up at the office every day following instructions, is not going to cut it. It is not how science is done, but it is also not how you could be happy doing it. It has to be what you want to do, otherwise it will be difficult to find the determination to do it. But if you do find it, you have the privilege of following your passion and that's the great thing about being a scientist.

As I alluded before, this is tampered a bit however, by the fact that you need to learn not to beat yourself up if you're not making progress. As I found out personally, you also have to know when to take breaks and let yourself rest. And especially, when to let your brain rest. Because in the end, what we do is a creative pursuit. You have to have an open and relaxed mind in order to make any progress. So, don't work yourself into the ground, but do pursue your passion, and do put in the grind in phases where progress is happening.

And finally, I do find that things are becoming more professionalised nowadays and I would advise against it. People more and more have a tendency to see science as a business *or a career that you have to somehow carefully plan. People are making a science career their business and start wondering more about things like "who do I have to talk to?", "how do I have to behave at conferences?", "how do I do this?" , "how do I impress?" etc. And for me, that is not the way to go. Because the core of our pursuit has to be the science and your passion for it. The problem with this professionalization is that in order to make a career in science, you also have to have a lot of luck and be at the right place, at the right time, facing the right problem. Trying to engineer your career to make things happen, is not the best way to go about it. First of all, it doesn't improve your chances all that much in the end, because it's the science that makes a career. And secondly, you might end up in a more desperate state of mind thinking you have tried everything but must have done something badly wrong when in fact it might not have even been your fault. I believe it is instead more important to work on being psychologically prepared to fail and not make it in science. It's unfortunate, but we all have to acknowledge that there's a great deal of luck involved. That also means that if things don't work, you don't have to beat yourself up too much about it. It may be just that you weren't there at the right time and the right problem passed you by, but it was not your fault.*

As someone involved in outreach activities, what have been the most rewarding and memorable moments you have experienced?

For me, the rewarding aspect of outreach is when you really feel that the audience is engaged and as fascinated by the subject as you are. And in fact, such moments happen quite often. You can still see and feel that people are captivated when you lecture to a large auditorium of lay people, just as well as when you show the experimental facilities at CERN to a small group of relatives or friends. And if you can transmit some information and why scientific research is important, and see that it really reaches people, that's the exciting part of outreach.

> To develop as an academic, I had to find early on my own language to talk about physics, and my own direction to pursue.

Another memorable part of outreach, are all the random interactions and interesting questions that people have. Typically, after an outreach lecture, there will be some time to talk to the audience. And often, people will ask very interesting questions, but ones that are different from the ones you get in an academic environment because their minds are freer in a certain sense. That can of course also be dangerous and go way off topic, but in my experience, it is mostly rather a positive experience. And what you get out of such interactions for yourself is usually a renewed confidence that what you're doing is important and people care about it.

There is also the hope that, just like I was motivated by reading science books by people who invested time and energy to disseminate their science, maybe your outreach activities will motivate younger people to pursue careers in science and have an impact on their lives. And maybe in the future, you even have an impact on science by helping bring in new talents.

Finally, I believe that scientists have a certain responsibility to society to explain what we're doing. What we do becomes a part of the cultural heritage of society, and as such, it would be meaningless if you couldn't disseminate it more widely than just within academic circles. So, I think it is also the role of a scientist to try and propagate what we learn further out into society.

Do you have any suggestions for fellow scientists who want to do outreach?

The most important suggestion, is that what you do is genuine and it shows how passionate you are about it. That's the sure-fire way to captivate an audience on any channel. The way you transmit your knowledge is also important and it's a good idea to try and be innovative and find new formats. A method that is often quite successful, is to use references to pop-culture, movies, music etc. and organise what you want to transmit around that. One example of this was when the movie Interstellar came out. We, that is at that time the Harvard and MIT outreach offices, organised a panel discussion centred around the topics that were raised in this film between various scientists such as gravitational theorists, cosmologists, and observational exoplanet scientist and others. The movie already had a full-throttle PR campaign, and we were able to tap into that and create interest in our event. Another successful method that I have seen some of my colleagues use, is social media and adapting scientific content so that it is more digestible on those platforms. They're usually short, encapsulated social media posts. Making a connection to things that fit into people's everyday lives is very useful, and cultural references are certainly one way do that.

> If you want to have an academic career, you have to work on what you're passionate about. It has to be what you want to do, otherwise it will be difficult to find the determination to do it. But if you do find it, you have the privilege of following your passion and that's the great thing about being a scientist.

You were a member of the Equal Opportunities committee. What would you recommend to encourage female researchers in science?

I think that the biggest impact would be societal change. The old perceived ideas that somehow, a career in science is more for a man, and an interest in science is something boys have, need to be addressed as soon as possible. And that is more a societal problem, than of the discipline itself. We should advocate for such changes, and be examples of not perpetuating these stereotypes. This is something I try do to myself personally, given that I don't share this opinion that science is a pursuit for men. I have a daughter, and I try to never make any remarks that could be interpreted wrongly. But the challenge is, that you can't shield a person from the society around them. So, even though within my family we certainly don't have that opinion, and we therefore also don't express it, there are still people around that might make misplaced remarks. For me, the change really has to start early on in school already, and perhaps more importantly also be accompanied by societal changes that alter the perceptions around science and math.

Another big challenge that is relevant in this context, is reconciling family and work. I am a man in science, but I take my responsibilities seriously between being a father, and how I organise my work, and it's often hard given the demands of the job for example with regards to travel. I would greatly advocate having childcare opportunities at work, conferences and so on. Even though there are far fewer women in the field, the need in this respect it is really more important for them, but ultimately in an egalitarian society it should be just as useful for a man than it is for a woman, and so advocating for such change as a man may be particularly effective.

As you see, most of these challenges are societal and occur in the way society organises the workplace and the family environment. And I believe changes there would make the biggest impact. Certainly, trying to address imbalances by the time people arrive at the University level, is too late.

Finally, to learn some more about you, when you are not doing research how do you spend your time? Do you have any personal hobbies outside of research?

A very important part of my life is always family and I spend most of my time outside of work with them. As for hobbies, I still play, and listen to a lot of music. I love playing the piano, recently Schubert and Janáček, and I have projects with other people around that in chamber music. But it is difficult to find the time for learning new pieces, I have to do it late at night on silent mode.

I also try to stay very active. I run and play tennis, and in the winter, I love being in the mountains, skiing and ski mountaineering. Those are my main hobbies.

And finally, if I have the time, I like reading as well, and not just my father's books of course. But as you can tell, there are too many things that I'm trying to do and most of the time, I have to make choices between them.

Conversation with Julian Sonner
Geneva/Online

Interviewed by Maria Kondratieva
On behalf of NCCR SwissMAP

Samir Canning

The Cohomology Of The Moduli Space Of Curves

The moduli space $\mathcal{M}_{g,n}$ of smooth curves of genus *g* with *n* marked points and its compactification $\overline{\mathcal{M}}_{g,n}$ by stable curves are objects of fundamental interest in many parts of mathematics and physics. Indeed, the moduli space $\mathcal{M}_g$ is the space of nonsingular, projective algebraic curves of genus *g*; it is the moduli space of isometry classes of hyperbolic metrics on a topological surface of genus *g*; it is the moduli space of conformal equivalence classes of Riemann surfaces of genus *g*. My research concerns the topology of these moduli spaces, especially the computation of their cohomology. The cohomology of these moduli spaces contains the answers to a variety of mathematical questions, ranging from physics to arithmetic [5, 8].

I will tell a story about how the topological perspective on the cohomology of $\mathcal{M}_{g,n}$ as the cohomology of a mapping class group combines with the algebro-geometric perspective. In the end, we obtain a complete computation of some of the low degree cohomology groups of $\overline{\mathcal{M}}_{g,n}$ for all *g* and *n*, a result that is not accessible using topology or algebraic geometry alone. The basic idea, going back to work of Arbarello and Cornalba [1], is to look at an exact sequence obtained from the long exact sequence in compactly supported cohomology and a bit of Hodge theory:

$$H^k_c(\mathcal{M}_g) \to H^k(\overline{\mathcal{M}}_g) \to H^k(\widetilde{\partial \mathcal{M}}_{g,n})$$

Here $\widetilde{\partial\mathcal{M}}_{g,n}$ is the normalization of the boundary $\partial\mathcal{M}_{g,n}$ of $\mathcal{M}_{g,n} \subset \overline{\mathcal{M}}_{g,n}$. Up to a finite group quotient, it is a disjoint union of spaces $\overline{\mathcal{M}}_{g-1,n+2}$ and $\overline{\mathcal{M}}_{g_1,n_1+1} \times \overline{\mathcal{M}}_{g_2,n_2+}$ for $g_1 + g_2 = g$ and $n_1 + n_2 = n$. In particular, the boundary is made up of moduli spaces of curves of smaller genera or with fewer marked points. If $H^k_c(\mathcal{M}_{g,n}) = 0$, then we are set up to study $H^k(\overline{\mathcal{M}}_{g,n})$ by double induction on *g* and *n*.

But when is $H^k_c(\mathcal{M}_{g,n}) = 0$? Algebraic geometry alone has little to say about this question. Using Strebel differentials, Harer showed that $\mathcal{M}_{g,n}$ is homotopic to a real 4*g* – 4 + *n* dimensional CW complex, at least when $g \geq 1$ [6]. Note that the real dimension of $\mathcal{M}_{g,n}$ is 6*g* – 6 + 2*n*. Therefore, the compactly supported cohomology $H^k_c(\mathcal{M}_{g,n}) = 0$ if $g \geq 1$ and $k < 2g - 2 + n$. Thus, topology allows us to argue inductively for g and n large relative to k. But what about the base cases?

There are a few methods of dealing with the base cases. Recently, Bergström, Faber, and Payne used point counting over finite fields and the Weil conjectures to compute cohomology for some new base cases [2]. As a result, they proved $H^7(\overline{\mathcal{M}}_{g,n}) = H^9(\overline{\mathcal{M}}_{g,n}) = 0$ for all *g* and *n*, extending Arbarello and Cornalba's result that $H^1(\overline{\mathcal{M}}_{g,n}) = H^3(\overline{\mathcal{M}}_{g,n}) = H^5(\overline{\mathcal{M}}_{g,n})$. The proof is quite difficult, and extending the point counting arguments to cover more base cases will be challenging.

Instead, Larson and I developed a different method based on algebraic cycles to study the base cases [3]. The key point is that these moduli spaces have explicit descriptions. For example, a smooth curve of genus 3 is either a plane quartic or a double cover of the Riemann sphere branched at 8 points. When *g* is sufficiently large, such descriptions are impossible because the moduli space $\mathcal{M}_{g,n}$ is of general type [7]. Using these descriptions, we can often compute the Chow groups $A^i(\overline{\mathcal{M}}_{g,n})$ completely. The Chow groups are algebro-geometric objects that admit maps to cohomology, which we are able to show are isomorphisms when *g* and *n* are sufficiently small. Using this new method, Larson, Payne, and I computed $H^{11}(\overline{\mathcal{M}}_{g,n})$, and together with Willwacher, we computed $H^{13}(\overline{\mathcal{M}}_{g,n})$ for all *g* and *n* [4,5]. In Figure 1, we illustrate the base cases needed to apply the inductive argument for the computation of $H^{11}(\overline{\mathcal{M}}_{g,n})$. It is not true that $H^{11}(\overline{\mathcal{M}}_{g,n})$ for all *g* and *n*, because $H^{11}(\overline{\mathcal{M}}_{1,11}) \neq 0$. Note that $\overline{\mathcal{M}}_{1,11}$ is one of the base cases.

Because we did not use point counting to establish the base cases, it is interesting to note that using the computations of $H^{11}(\overline{\mathcal{M}}_{g,n})$ and $H^{13}(\overline{\mathcal{M}}_{g,n})$, we can obtain results about counting curves of genus *g* over finite fields of size *q*. That is, about the function from prime powers *q* to $\#\mathcal{M}_g(\mathbb{F}_q)$. With Larson, Payne, and Willwacher, we prove that this function is given by a polynomial expression in *q* if and only if $g \leq 8$ [5, Theorem 1.1]. Previously, it was known only that $\#\mathcal{M}_g(\mathbb{F}_q)$ is polynomial if $g \leq 4$.

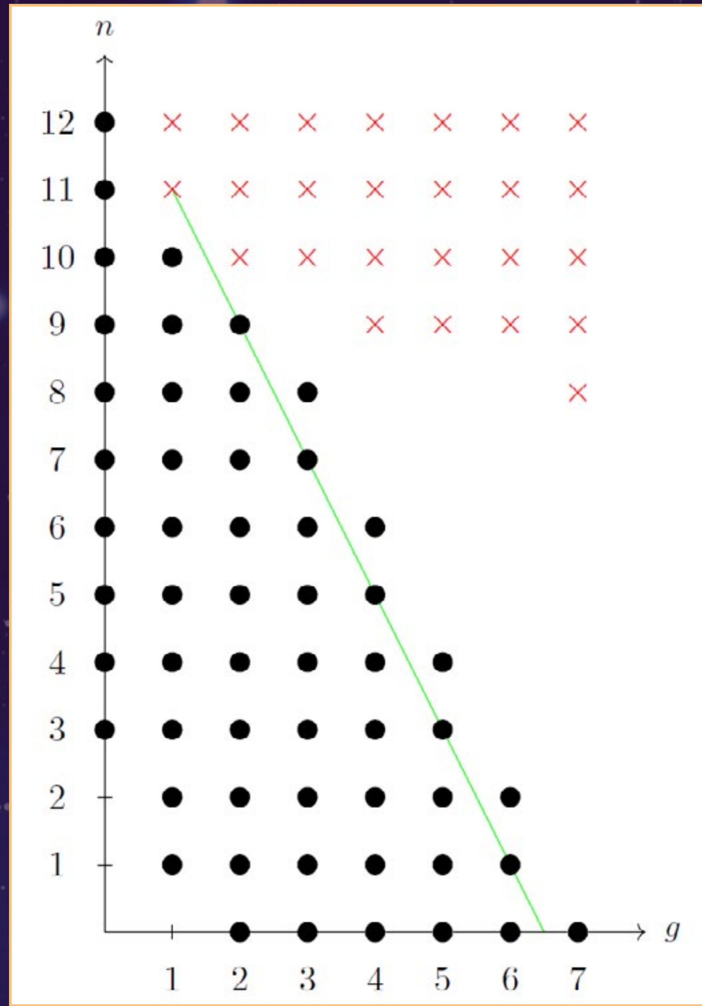


Figure 1. An illustration of the base cases needed for the computation of $H^{11}(\overline{\mathcal{M}}_{g,n})$. Entries on the green line or below and to the left of it are the base cases. • at (*g*, *n*) means all odd cohomology of $\overline{\mathcal{M}}_{g,n}$ vanishes. × at (*g*, *n*) means there exists odd cohomology on $\overline{\mathcal{M}}_{g,n}$.

References

[1] Enrico Arbarello and Maurizio Cornalba, *Calculating cohomology groups of moduli spaces of curves via algebraic geometry*, Inst. Hautes ´Etudes Sci. Publ. Math. (1998), no. 88, 97–127. MR 1733327

[2] Jonas Bergström, Carel Faber, and Sam Payne, *Polynomial point counts and odd cohomology vanishing on moduli spaces of stable curves*, Ann. of Math. (2) **199** (2024), no. 3, 1323–1365. MR 4740541

[3] Samir Canning and Hannah Larson, *On the Chow and cohomology rings of moduli spaces of stable curves*, To appear in Journal of the European Mathematical Society, arXiv preprint arXiv:2208.02357 (2022).

[4] Samir Canning, Hannah Larson, and Sam Payne, *The eleventh cohomology group of* $\mathcal{M}_{g,n}$, Forum Math. Sigma **11** (2023), no. e62, 18 pages.

[5] Samir Canning, Hannah Larson, Sam Payne, and Thomas Willwacher, *Moduli spaces of curves with polynomial point counts*, arXiv preprint arXiv:2410.19913 (2024).

[6] John L. Harer, *The virtual cohomological dimension of the mapping class group of an orientable surface*, Invent. Math. **84** (1986), no. 1, 157–176. MR 830043

[7] Joe Harris and David Mumford, *On the Kodaira dimension of the moduli space of curves*, Invent. Math. **67** (1982), no. 1, 23–88, With an appendix by William Fulton. MR 664324

[8] Edward Witten, *Two-dimensional gravity and intersection theory on moduli space*, Surveys in differential geometry (Cambridge, MA, 1990), Lehigh Univ., Bethlehem, PA, 1991, pp. 243–310. MR 1144529

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Romain Panis

Presenting my research

My research focuses on the mathematical study of *phase transitions* in statistical mechanics. I am particularly interested in their occurrence in *magnets*.

In 1895, the French physicist Pierre Curie discovered that magnets lose their defining property when heated beyond a certain *critical temperature*. To explain this phenomenon, Wilhelm Lenz and his student Ernst Ising introduced the *Lenz–Ising model* in the 1920s. This model provides a mathematical framework to explain Curie's observations, proposing that a magnet consists of a collection of tiny *dipoles*, whose overall orientation determines the magnet's strength. For simplicity, one can assume that these dipoles are located on the vertices of the hypercubic lattice $\mathbb{Z}^d$ with $d \geq 1$. Each dipole carries a *spin* that can take the values −1 or +1. A spin configuration $\sigma \in \{-1,+1\}^{\mathbb{Z}^d}$ is distributed according to a probability measure that reflects the physical intuition: neighbouring spins tend to align in the same direction, while the thermal agitation creates disorder. Formally,

$$\mu[\{\sigma\}] = \frac{1}{Z}\exp\Big(\beta\sum_{x\sim y}\sigma_x\sigma_y\Big), \quad (1)$$

where β is the *inverse temperature*, Z is a normalisation constant, and $x \sim y$ means that x and y are neighbours in $\mathbb{Z}^d$. One may also define the *spontaneous magnetisation* $m^*(\beta)$ (which corresponds to the strength of a magnet at parameter β). This quantity undergoes a *phase transition* when $d \geq 2$ in the sense that there exists some *critical parameter* $\beta_c \in (0,\infty)$ such that $m^*(\beta) = 0$ when $\beta < \beta_c$ and $m^*(\beta) > 0$ when $\beta > \beta_c$, see Figure 1 for a simulation of the model.

One of the key challenges in statistical mechanics is to understand the behaviour of the model near or at the critical point β_c. This can be done both qualitatively and quantitatively. A significant qualitative result is the (recent for d = 3) proof that the spontaneous magnetisation vanishes at criticality: $m^*(\beta_c) = 0$. To reach a more quantitative description of the near-critical regime, one can compute the model's *critical exponents*. For example, physicists predict the existence of the exponents $\hat{\beta}$ and η defined by

$$m^*(\beta) = (\beta_c - \beta)^{\hat{\beta}+o(1)},$$

$$\mu_{\beta_c}[\sigma_x\sigma_y] = \frac{1}{|x-y|^{d-2+\eta+o(1)}}, \quad (2)$$

where $o(1)$ tends to 0 as $\beta \searrow \beta_c$ or $|x-y| \to \infty$. Conducting this last task is in general extremely challenging as it involves in a very subtle way the geometry of the lattice $\mathbb{Z}^d$.

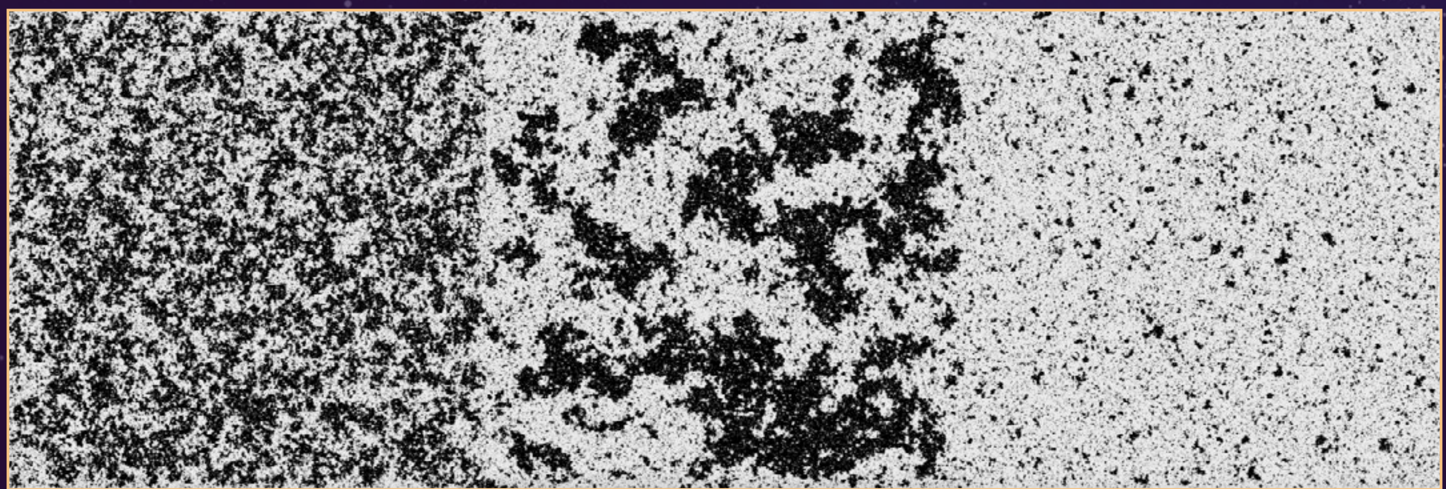

Figure 1: Samples of the Ising model in a box of size 1024 × 1024. White (resp. black) dots correspond to a +1 (resp. −1) spin. From left to right: $\beta < \beta_c$, $\beta \approx \beta_c$, and $\beta > \beta_c$. In the *subcritical* regime $\beta < \beta_c$, spins are disordered: +1 and −1 spins are balanced. In the *supercritical* regime $\beta > \beta_c$, spins are ordered and tend to align in the +1 direction (with small fluctuations). In the (near-)critical regime $\beta \approx \beta_c$, *fractal* structures (related to SLE(3) and CLE(3) curves) emerge and the picture is much more complex (and richer). The simulations are due to Raphaël Cerf.

Theoretical physicists made a remarkable prediction in the 20th century: above a so-called *uppercritical dimension* d_c, the model's near-critical behaviour drastically simplifies. When $d > d_c$ — i.e. in the *mean-field regime* of the model— the geometry of the lattice ceases to play a crucial role, and the critical exponents take a simpler form, matching those of the model defined on a Cayley tree. For the Ising model, one expects $d_c = 4$ and $(\hat{\beta}, \eta) = (\frac{1}{2}, 0)$ when $d > 4$. A similar behaviour is anticipated for a broad class of models, including *Bernoulli percolation*, where the upper-critical dimension is expected to be $d_c = 6$.

Prominent methods such as the lace *expansion* and rigorous *renormalisation group methods* have been developed in the 1980s to confirm these predictions. A limitation of these approaches lies in their predominantly perturbative nature which requires to exhibit a *small parameter* within the system of study. This parameter can be taken to be $\frac{1}{d-d_c}$, which means that one may recover mean-field features for the model in dimensions much larger than d_c. This leaves a gap to fill to understand the entire mean-field regime of a model. Furthermore, while these methods are employed to study probabilistic models, they rely on intricate analytic arguments that are highly sensitive to the specific model under consideration.

Together with Hugo Duminil-Copin, we revisited this classical problem and provided a new perspective that (essentially) gives a unified treatment of these perturbative regimes. Unlike the other approaches, we rely on soft *random walk estimates*, thus providing a probabilistic justification to the emergence of the mean-field behaviour in sufficiently large dimensions. Our method applies to other models such as the XY model, the φ^4 model, or Bernoulli percolation.

Similarly to the lace expansion, we use *path expansions* of the model, which provide random walk interpretations of the quantities of interest. Using this perspective, we show that the *two-point function* $\mu_\beta[\sigma_x\sigma_y]$ of the model can be compared to the (massive) Green function of an *effective* random walk. This step drastically differs from the lace expansion as we only rely on inequalities rather than exact identities. Classical arguments then allow to derive a proper analysis of the critical two-point function, which leads to a new proof that $\eta = 0$ when the dimension is large enough. In upcoming works with Hugo Duminil-Copin, Aman Markar (Genève), and Gordon Slade (Vancouver), we hope to build on this new approach to get closer to a full description of the mean-field regime $d > d_c$ for a large class of models.

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UNIGE, H. Duminil-Copin's group

Aleksandr Trufanov, master's student at the University of Geneva and recipient of the SwissMAP grant, looks back on his past two years at UNIGE and with SwissMAP, and shares his plans for the future.

Interview: Aleksandr Trufanov

Academic background and interdisciplinary journey

Could you tell us about your academic journey before coming to Geneva?

I completed both my Bachelor's and my first Master's degree at MIPT (Moscow Institute of Physics and Technology). I've always maintained a balance between physics and mathematics.

How did the transition from physics to mathematics occur in your studies?

Actually, there wasn't a sharp transition—I've always engaged with both fields. Research often involves exploring unfamiliar concepts and their connections. Although a step-by-step approach (definitions → propositions) works, it can slow things down and miss the bigger picture. In physics, dealing with less-formal definitions and working intuitively—as a "black box"—taught me to use and explore concepts before fully formalizing them, which has been invaluable in mathematics.

How did your background in physics influence your approach to mathematics?

That "physical intuition" has carried over. While rigorous understanding is essential, first getting a sense of why something matters—its philosophy—can ease the formalization. My experience in physics helped me develop this intuitive approach to abstract mathematical ideas.

Were there challenges or advantages in having an interdisciplinary background?

One challenge is that my mathematical foundation might have been deeper had I focused solely on mathematics. On the flip side, working across disciplines helped me make more informed decisions about my interests and direction.

Your experience in Geneva

How would you describe your two years in Geneva, both academically and personally?

Studying in Geneva was a wonderful opportunity. The city is vibrant, offering concerts, sports, and many student events.
Academically, beginning research in a brand-new area was the most significant experience. It took about a year to formulate a research question meaningful both to my supervisor, Andras Szenes, and to me. One of the hardest things was working without intuitive understanding of the objects involved. Eventually, I found a question I felt passionate about.

Is there a particular memory from your time at the University of Geneva that stands out?

I greatly appreciated the intellectual atmosphere in the Department of Mathematics. Professors—and especially Andras—consistently conveyed material clearly and insightfully. Even basic lectures were delivered with elegance and depth, and much of what I learned was directly useful in my research. These two years truly enriched my mathematical outlook.

How did your supervision in Geneva influence your path?

Andras's mentorship was pivotal. He balanced offering thoughtful guidance without imposing a strict path. That encouraged both independence and reflection in my research approach.

Did you connect with other researchers during your time in Geneva?

Yes—through conferences and departmental events I regularly interacted with professors and fellow students. These exchanges were both intellectually stimulating and inspirational.

How was your experience as part of the SwissMAP community?

It was a privilege. I valued participating in SwissMAP conferences and events, which enriched my motivation, ideas, and research.

What comes next

You're now in Montreal for your PhD. Could you tell us a bit more about your current research project?

I'm in my first year of a PhD at Université de Montréal under Leonid Rybnikov. This project isn't directly connected to my work with Andras, but relates more to my earlier research. I'm still collaborating with him as well. With Leonid, we're preparing a paper based on our recent results. The project with Andras also made significant strides during my June visit to Geneva.

How did your time in Geneva prepare you for this next step?

Geneva was my first experience abroad and a warm, welcoming environment. The mathematical culture and research discipline I developed there are proving invaluable as I begin my PhD.

Conversation with Aleksandr Trufanov
UNIGE

Interviewed by Mayra Lirot
NCCR SwissMAP

Hugo Duminil-Copin
Co-Director

Elise Raphael
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Shaula Fiorelli
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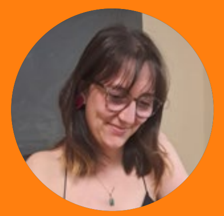

Pauline Baudat
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The SwissMAP Outreach Landscape and G·EM

As SwissMAP approaches its conclusion in 2026, after eleven years of groundbreaking research, its impact extends well beyond scientific publications and collaborative networks. One of its most significant achievements is the SwissMAP Research Station (SRS) in Les Diablerets, dedicated to high-level research. In parallel, SwissMAP has also supported a variety of outreach activities that have flourished in Zurich and Geneva, which also form part of SwissMAP's lasting legacy.

In Zurich, the ETH Zurich Youth Academy and the UZH Junior Euler Society have for years successfully provided students with structured opportunities to engage with mathematics beyond the classroom.

In Geneva, this dynamic took a new step forward with the launch of Genève Évasions Mathématiques (G·EM) in 2024, a structure designed to bring together existing initiatives and foster new ones, offering a visible and coherent platform for public engagement. G·EM carries out its mission through a wide range of accessible formats targeting diverse audiences, including festivals, public conferences, exhibitions, and a dedicated strand focused on gender and inclusion. It also organises activities for education and science communication professionals, and offers extracurricular programmes specifically designed for school-aged audiences. In parallel, G·EM collaborates with partner organisations to co-create outreach projects across a variety of contexts.

G·EM is led by a small but dedicated team combining expertise in research and science outreach. Elise Raphael, Scientific Officer for SwissMAP and the SwissMAP Research Station, and Hugo Duminil-Copin, Fields Medalist, serve as Co-Directors. The core team includes Shaula Fiorelli, Coordinator and Project Manager, who also heads Mathscope, part of the UNIGE's outreach platform Scienscope; Mayra Lirot, in charge of communication; and scientific assistants Pauline Baudat, Vera Bossart and Cesar Humerose as well as Charlotte Guarino, who provides administrative support.

The inauguration of G·EM in 2024 took place in September through the Math'émerveille festival, held at the Musée d'Histoire des Sciences in Geneva. The event drew over 1,800 visitors, a record attendance for the museum, and brought together a diverse public of all ages and backgrounds. The enthusiastic response confirmed both the relevance of the initiative and the public's growing interest in engaging in accessible mathematical experiences.

What's new since the creation of G·EM?

A growing set of initiatives designed to strengthen public engagement, which fall into several key projects. They include among other ongoing and emerging initiatives:

Promoting gender inclusion in mathematics
The "Filles et Maths" strand brings together a series of initiatives designed for school-aged girls. It includes Les Marmottes, a long-standing workshop, as well as Les Mini-Marmottes, a recently launched weekend programme held at the University of Geneva. The initiative also features Une mathématicienne dans votre classe, which connects women mathematicians with school classrooms to foster dialogue and provide visible, relatable role models. Thanks to recent MINT funding, these activities will soon be extended across French-speaking Switzerland.

Creating new spaces for dialogue with the public
The public lecture series Maths à PartaG was created to open up conversations between mathematics and broader society. Some events feature mathematicians in dialogue with guests from other disciplines. Three talks have already taken place Nombres Mystérieux with Francis Brown (Oxford University), La Joie des maths with David Cimasoni (UNIGE), and Comment être élu à tous les coups? with Jean-Baptiste Aubin (Université de Lyon) each offering a fresh perspective on mathematics and drawing an engaged, curious audience.

Establishing new traditions through public events
Pi Day is quickly becoming a yearly tradition in Geneva aimed at a broad audience. The first edition, in 2024, took the form of a collaborative public challenge: Défi Carré du Diable, inviting participants to explore logic and geometry in a hands-on, playful format.
In 2025, Pi Day featured the exhibition Kolam: a women's and ephemeral art from South India. The exhibition highlighted the intersection between mathematics and cultural tradition through intricate geometric designs

passed down through generations of women. It was accompanied by a two-part public lecture Anthropology and Mathematics of Kolam delivered by Claudia Silva (UNED) and Oscar Garcia-Prada (ICMAT), offering both anthropological and mathematical perspectives on this unique practice. The programme also included hands-on workshops, inviting participants of all ages to experiment with creating their own kolam patterns.

A growing festival
This summer saw the second edition of the Math'émerveille festival in Geneva, held in July at the Musée d'histoire des sciences. Building on the success of its first edition, the festival offered a wide-ranging programme for all ages and confirmed the public's strong enthusiasm for this kind of event. It is now set to become a recurring biennial gathering, bringing together a diverse array of professionals from Geneva, across Switzerland, and Europe.

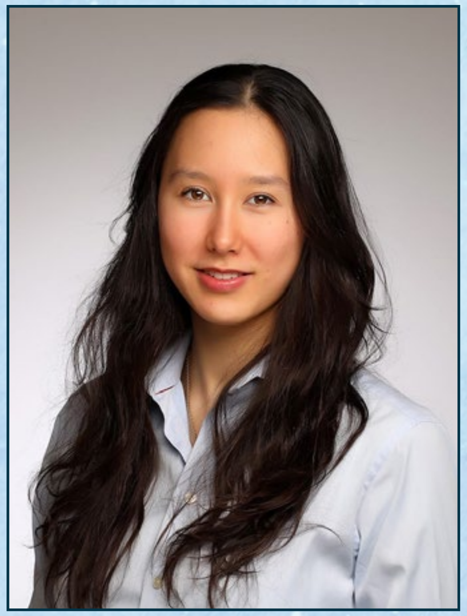
A Lasting Vision
With the creation of G·EM in Geneva and the continued work of long-standing initiatives in Zurich, SwissMAP leaves behind a strong and lasting outreach presence. Together, they reflect a shared belief that mathematics is not something abstract or cut off from the world, but a human pursuit enriched by dialogue, curiosity, and connection.

To follow G·EM's activities
Subscribe to to the G·EM newsletter where we regularly share recordings of public events and conferences.
Or visit www.unige.ch/math/GEM

G·(EM) Évasions Mathématiques

An interview with Clara Cossin, a former participant in the SPRING and ATHENA programs at UNIGE, recently admitted to Stanford. An inspiring journey, marked by doubts, discoveries… and a genuine passion for mathematics.

From SPRING to ATHENA: A Journey into Mathematics



When Math Started to Make Sense

What made you want to pursue mathematics?

"At first, I thought of math as something very abstract… I didn't really see how it could be useful in real life. But after spending some time at EPFL and reading a lot, I realized just how fundamental mathematics is to the structure of our society. I've always loved logic, and this realization changed everything. I wanted to dive in seriously."

Helping People Appreciate Math: the Essential Role of Teachers

In your opinion, what could be done to help young people discover mathematics better?

"For me, it all starts with the teachers. I was lucky to have teachers who encouraged me to go further, to read more advanced books even when I didn't understand everything. School often gives a very misleading impression of mathematics as a difficult, abstract, and stressful subject. We need to help curious students get beyond that first impression."

Two Programs, Two Approaches: One Shared Momentum

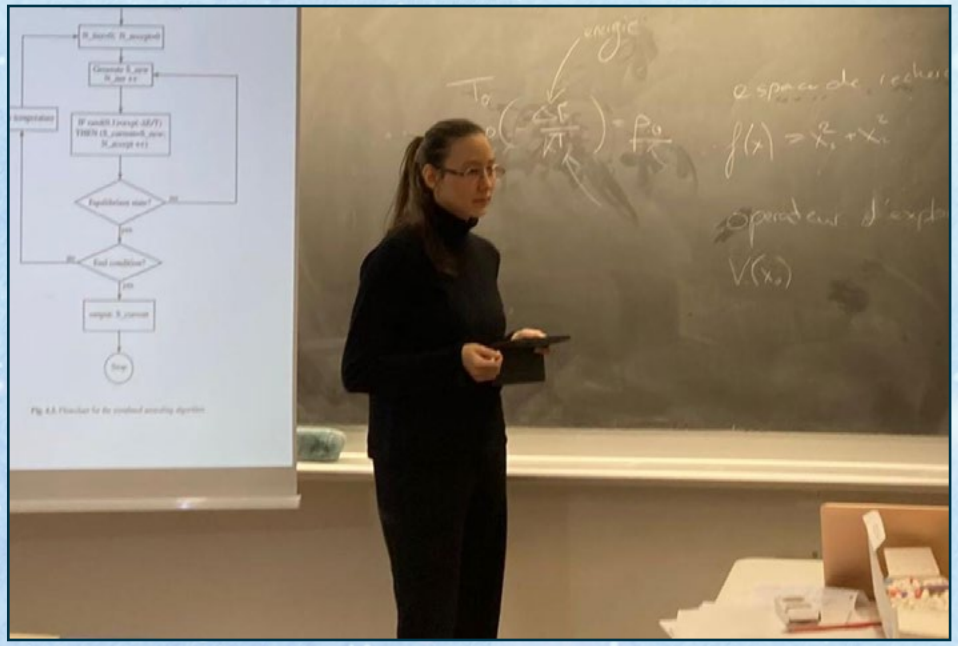
When Clara discovered that UNIGE offered the ATHENA and SPRING programs, she didn't hesitate.

"I knew I liked math, but I felt I needed a structured environment to make progress. For me, it was a real opportunity… almost like opening a door to another world."

Both experiences were very different but deeply complementary.

With ATHENA, Clara got a concrete taste of university life. She attended undergraduate math courses with personalized support in the form of tutoring. What stood out for her? The chance to talk with university students, share their daily life, and above all, gradually feel that she belonged in the mathematical community.

"Before, I thought of mathematicians as inaccessible geniuses… At UNIGE, I discovered kind, passionate, and very human people. Conversations with professors, students, and teaching assistants showed me that math isn't just about theorems and numbers. It's a way of thinking that also shapes how we see the world."



SPRING, on the other hand, gave her a different kind of learning experience, freer and more collaborative. At first a little skeptical about this approach, based on collectively reading a mathematics book, Clara quickly got into it. The weekly discussions, the exchange of ideas, and the freedom to explore concepts in depth allowed her to go much further in her understanding.

"ATHENA gave me a glimpse of university life, while SPRING taught me to think differently and to talk about mathematics freely. Both brought me so much, in very different yet perfectly complementary ways."

Being a Woman in Mathematics…

Did being a woman in a field still dominated by men affect your journey?

"At UNIGE, I always felt very welcome. I never felt I was treated differently because I was a woman, and that really helped me feel like I belonged in the mathematical community.
But it's true that in other settings, being the only woman among 30 men… even if no one said anything negative, you inevitably feel a bit different, a bit scrutinized.
I think it's important to say: it can be intimidating to be a woman in a field that's still very male-dominated, but experiences like ATHENA and SPRING gave me the confidence I needed to keep moving forward."

Inspirations in Math and Beyond

Were there people who particularly inspired you on your journey?

"Yes, first and foremost, the mathematical community at UNIGE really left its mark on me. It gave me confidence and helped me feel legitimate, even though I knew I wasn't at the same level as many others at the university. There's a lot of kindness, and above all a contagious passion for mathematics.
I was deeply impressed by the teachers, people who know an extraordinary amount yet remain very humble and approachable.
My faith also supported me throughout my journey. It gave me the strength to persevere, the confidence that things would fall into place, and the sense that I was not alone in facing difficulties.
In life, Steve Jobs particularly inspires me, not necessarily for his ethics, but for his audacity, his ability to seize opportunities, to jump in without hesitation, to fall and then get back up. I admire this idea of moving forward without fear of the unknown, of taking risks. One of his quotes that inspires me deeply is this one:
"The people who are crazy enough to think they can change the world are the ones who do."

A Mathematician… and a Musician

Have you always known you wanted to study math?

"Not really. If I hadn't participated in SPRING and ATHENA, I might have chosen music, I'm a violinist, or perhaps fields like mechanical engineering or robotics. But those two programs really confirmed my desire to pursue mathematics.
Now I'm heading to Stanford, where I'll be able to combine both: studying for a bachelor's degree in mathematics while continuing with music."

A New Adventure at Stanford

How did you react when you learned you'd been admitted to Stanford? And what excites you most about this next chapter?

"When I got the reply, it was incredible. For me, it was a bit like reliving the excitement I felt when I joined ATHENA… but on a whole different scale! It felt like a door opening onto a new world.
What excites me the most is being able to keep studying mathematics while also continuing with music, which has been a big part of my life for more than thirteen years. At Stanford, it's very common to pursue multiple tracks in parallel, and that will allow me to keep pursuing both of these passions."

Conversation with Clara Cossin
Former participant in the SPRING and ATHENA programs at UNIGE

Interviewed by: Mayra Lirot
NCCR SwissMAP

Alumni Corner

François PAGANO

François left UNIGE in 2025 after obtaining his PhD under the supervision of Aleksandr Logunov, focusing on Partial Differential Equations. He now works as an energy trader for Alpiq.

You began your academic journey at EPFL, earning degrees in both mathematics and financial engineering. What led you to pursue a PhD in pure mathematics afterward?

I was always interested in both mathematics and finance. At the end of my Bachelor degree in mathematics, I decided to go on the financial engineering path, which allowed me to study finance and mathematics altogether. To complete my master degree, I had to do an internship in the industry. I did mine in a bank in Paris. I really enjoyed it and got the opportunity to move to London to work within the same team, first as an intern and then as a trader. It was a great experience, I learned a lot about the financial industry and its challenges. But at the same time, I wanted more and more to learn about all the pure mathematics that I did not have the opportunity to study in my master's degree. And that is why I resigned from my position and started with a second master, this time in mathematics. After my master, I was lucky enough to join the research group of Sasha Logunov at UNIGE to do my PhD and to continue learning about pure mathematics.

During your PhD at the University of Geneva, you worked in Alexander Logunov's group on problems related to partial differential equations and harmonic analysis. Could you tell us more about the focus of your doctoral research?

My PhD was focused on quantitative properties of solutions to some partial differential equations. At the bachelor level, we learn about complex analysis and the fact that holomorphic functions have the unique continuation property: if they are zero on an open set then, they vanish everywhere. Solutions to some pdes share the same property. A quantitative version of this statement can take the form: how fast can a solution to some pde decay to zero at infinity without being identically zero? That is, how close to zero can a solution be without being the trivial solution? Some results were known but a lot was still open. It turns out that this problem, which seems a priori purely pde-related, has a strong connection to physics. The speed of decay of solutions to the Schrödinger equation for a particle in a material is related to the physical properties of this material, whether this material will conduct electricity or not. I really enjoyed working on this topic. I also had the opportunity to work on problems from Fourier theory and stochastic homogenization theory.

What did you find most intellectually stimulating or personally rewarding during your time as a PhD student?

I really enjoyed continuously learning and discovering new things. Mathematics is a wide field and even topics that seem distant are in fact connected. I find that really beautiful. I also had the opportunity to collaborate with different researchers, both within and outside UNIGE, attend conferences, present my research and that was also a great experience. Sharing and discussing mathematics with different people is rewarding.

You've now transitioned into industry and are working at Alpiq. Can you tell us about your current position and how your academic background feeds into your work today?

Alpiq is a producer of electricity who owns several assets both inside and outside Switzerland. I work as an asset trader, in the team responsible for managing gas power plants. My day to day involves trading gas, power and carbon certificates in different European markets, to hedge market movements and optimize our assets. Managing an asset, like a thermal or a hydro plant, can be explained mathematically through an optimization problem. I use my academic background to get a deep understanding of this optimization and translate it in practice in the best possible way.

How did your time within the SwissMAP community shape your perspective on mathematics or influence your career choices?

What I enjoyed about SwissMAP is that it connects mathematicians through the organization of various conferences. It allowed me to meet new colleagues and discuss mathematics outside the formal university setup. I have in mind the research station in Les Diablerets, which allows for easy discussions with different people, not necessarily directly working on the same topic as me. And this is very helpful for a mathematician and can often lead to new ideas.
I also had the opportunity to participate in Mathscope, which is supported in part by SwissMAP. It's a great program which introduces mathematics through games, curiosity and experience to young children. It's very rewarding to see kids understand patterns and make connections of their own. They were engaging in mathematical reasoning without having the feeling that they are doing it and I am convinced that this will spark curiosity in some of them to continue exploring mathematics in the future.

What advice would you give to other young researchers who might be considering a move from academia to industry?

I would encourage them to do internships, as early as possible, to get a first feeling. Not to rush into anything but try different things, to see what they enjoy the most and what are the different options. It is also helpful to meet and discuss with people in the industry to get a better understanding of the field and the requirements. Having academic experience is, I think, a big plus in the industry as we learn many skills in academia that are highly sought after in the industry: problem-solving skills, presentation skills, managing different projects simultaneously. Working in the industry can be as stimulating and intellectually rewarding as working in academia. It's a great career choice.

Looking back, is there a particular highlight or defining moment from your PhD experience that stands out?

I would say the moments when you understand how to tackle a problem are really rewarding. But the highlight would be when you solved your problem and you had to write it down. It's not easy to write a mathematical paper in a clear way but when after a couple iterations you have been able to write it down clearly, you really see how far you went. All the progress, from the initial problem to a clear solution on paper. This is for me the most rewarding part.

Finally, how do you stay connected to mathematics in your current role, or outside of it?

My current position involves working with mathematical models, understanding practical implementation, so I still have a connection to mathematics. But I also look from time to time at recent mathematical publications related to my PhD topics to see how the field is advancing. When you do a PhD, you really enjoy mathematics and this is not something that goes away easily.

SwissMAP continously strives to maintain a strong connection between all past and present members. Our alumni corner presents inspiring stories from some of our previous members.

Conversation with F. Pagano
Formerly: UNIGE, A. Logunov's Group

Upcoming Events

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. Medellın)

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

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NCCR SwissMAP Final Event

September 2026 at the SRS in Les Diablerets
Next year's Annual General Meeting will also mark the final SwissMAP event. The date will be confirmed and communicated to all members. The event will be a moment to celebrate all that has been accomplished over more than a decade of shared scientific effort. While it marks the end of the NCCR, it also opens the door to what comes next: sustained collaborations, lasting structures, and a community that will continue to grow and evolve beyond 2026.

It will showcase the major scientific contributions made during the third and final phase of SwissMAP. Informal networking moments will offer opportunities for current members, alumni, and invited guests to reconnect, exchange ideas, and spark new collaborations.

The event will also provide an opportunity to reflect on the enduring foundations that will carry SwissMAP's vision forward. At the core of this legacy is the SwissMAP Research Station in Les Diablerets, which will continue to foster international collaboration and advanced research. In addition, outreach initiatives developed during the NCCR, some of which will continue in Geneva and Zurich, will be presented, highlighting efforts to extend SwissMAP's reach beyond the academic world.

The program will include a poster session and a conference dinner. A closed session will also be held to discuss the final report with NCCR management, representatives from the home institutions, and the SNSF Review Panel, marking the conclusion of an ambitious and collaborative scientific journey.

Past Events

Video recordings of the following previous events are available through playlists on our NCCR SwissMAP YouTube channel.

2025

- 2025 SCGCS School – Topological Symmetries and Defects in QFT (Jun 15 – 20)
- The Amplituhedron: Structure, Combinatorics, and Positive Geometry (Jun 29 – Jul 4)
- Polylogarithms, homology of linear groups, and Steinberg modules (June 8 – 13)
- Effective theories for many-body systems out of equilibrium (May 11 – 16)

2024

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

Awards & Grants

Juhan Aru
Promoted to Associate Professor

Congratulation to Juhan Aru who has been promoted to Associate Professor at EPFL's School of Basic Sciences. Juhan Aru's award-winning research has a focus on probability theory and stochastic analysis, particularly the Gaussian Free Field theory – a highly competitive and important research area.

Mikaela Iacobelli
SNSF Starting Grant

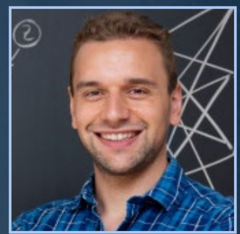
Congratulations to Professor Mikaela Iacobelli. She is one of eight candidates from ETH Zurich who have received a Starting Grant from the Swiss National Science Foundation (SNSF).

Nicolas Gisin
Micius Quantum Prize

We are thrilled to announce that our esteemed member Nicolas Gisin has been awarded the prestigious Micius Quantum Prize. This recognition is a testament to his significant contributions in the field of quantum science.

Alejandro Pozas-Kerstjens
SNSF Postdoctoral Fellowship

Alejandro Pozas-Kerstjens (UNIGE, N. Gisin's Group) was awarded an SNSF Postdoctoral Fellowship for the project: *Certification and cryptography in quantum networks.* The project will run from 01.09.2024 – 31.08.2026.



Vincent Vargas
Speaker at ICM 2026

Vincent Vargas will speak at the ICM 2026 about the equivalence between the probabilistic construction of Liouville field theory and the celebrated bootstrap construction used in physics. He is currently working on the harmonic analysis of Gaussian multiplicative chaos.

Maryna Viazovska
Honored by Sorbonne University &
2025 Fejes Tóth László Prize and Medal

Among eight distinguished figures recognized this year, Sorbonne University awarded an honorary doctorate to Maryna Viazovska for her groundbreaking work in mathematics.
She has also been awarded the Fejes Tóth László Prize and Medal by the Rényi Institute of Mathematics. This honor recognizes her pioneering work in discrete geometry and number theory

SwissMAP Junior Researcher Prize

SwissMAP and G-Research invite nominations and applications for the SwissMAP Junior Researcher Prize 2025

Deadline for nominations & applications:
September 15, 2025

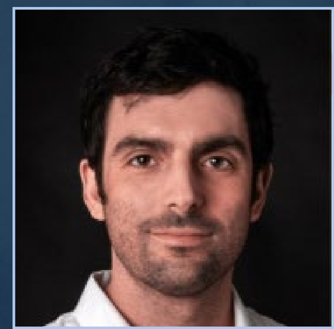
* Up to three prizes will be awarded once a year to PhD students or Postdoctoral researchers for important scientific achievements in Mathematics and Theoretical Physics, supported by G-Research.
* The call is open to all PhD and postdoctoral researchers (maximum 5 years after PhD completion) in mathematics and theoretical physics enrolled in a Swiss institution at the time of application.
* We welcome self-nominations as well as nominations by PhD advisors and postdoctoral mentors.

Freya Behrens (EPFL)
Samir Canning (ETHZ)
Romain Panis (UNIGE)
2024 Winners
Congratulations to the first SwissMAP Junior Researcher Prize recipients.

New Members

Andrea Agazzi
UNIBE

Welcome to our new member: Andrea Agazzi (UNIBE). He joined the *Statistical Mechanics and Random Structures* and *Differential equations of Mathematical Physics* SwissMAP Phase III Directions.
Anrea's research lies in in applied probability theory, more specifically in interacting particle systems for real world applications.



Alexander Hock
UNIGE

Welcome to our new senior reearcher: Alexander Hock (UNIGE), who has joined M. Mariño's group. Alexander's research lies in mathematical physics, at the intersection of algebraic geometry, noncommutative geometry, topology, combinatorics, and probability theory in mathematics, as well as string theory, quantum field theory, and gravity in physics.

Puzzle Corner

1. Division trick

Someone thinks of a natural number between 1 and 100.

You ask this person for the remainders when dividing by 3, by 5, and by 7. Once you know these remainders, you can quickly determine the number.

How does this trick work?

2. Magic and Anti-Magic

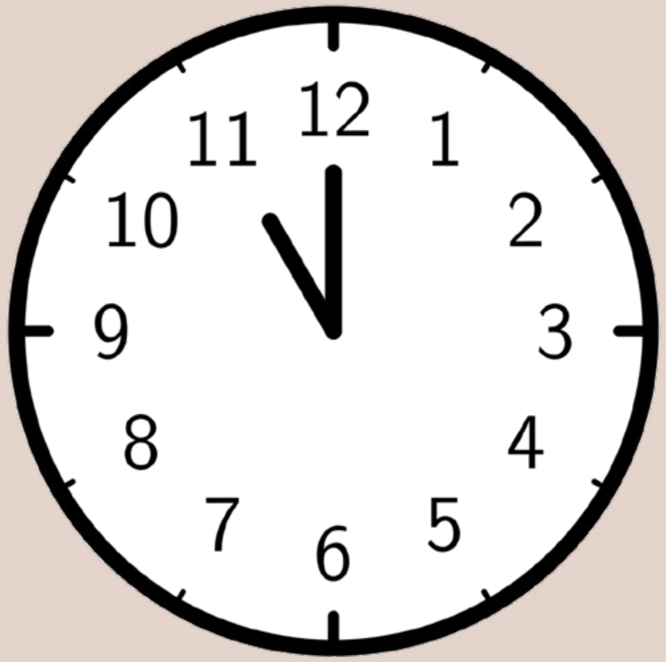
In a magic square, the sums of the numbers in the rows, columns, and main diagonals are always the same, as in this example:

2	7	6
9	5	1
4	3	8

Is it possible to arrange the numbers 1 to 9 in a 3×3 square in an anti-magic way, i.e. so that all sums of the numbers in the rows, columns, and main diagonals are different in pairs?

3. The clock face

Divide the clock display into three parts so that the sum of the digits in each part is 17:



4. Numerical alphabet

In the equations listed below with the first 10 letters of the alphabet a, b, c ... j, the letters must be replaced by the digits 0, 1, 2, 3 ... 9 in such a way that all equations are correct:

a : b = c, c + d = e, e − f = g, g × h = 10 × i + j

5. Ways to reach 0

You can place arithmetic operators (+,−,x,:) between the digits of the number

a) 123456789

b) 987654321,

e.g. 98 + 7x6 − 5x4 + 3 + 2 + 1.

The goal is to obtain the result 0 using as few operation symbols as possible.

Answers

1. Division trick

Take the remainders r3, r5, and r7 and calculate 70 x r3 + 21 x r5 + 15 x r7. The result is either the number you thought of or the number that is 105 greater.

2. Magic and Anti-Magic

1	5	3
2	7	6
4	8	9

3. The clock face

The groups of numbers are

17= 2 + 1 + 2 + 3 + 4 + 5= 1 + 1 + 8 + 7= 1 + 1 + 0 + 9 + 6

Part A contains the right side up to and including 5 and the number 2 from 12.

Part B contains the left edge of the clock with the digits 1 from 10 and 11 and the numbers 8 and 7.

Part C is the rest: 1 from 12, 1 from 11, 0 from 10, the 9 and the 6.

4. Numerical alphabet

a = 6, b = 3, c = 2, d = 7, e = 9, f = 1, g = 8, h = 5, i = 4, j = 0

6 [illegible] 3 = 2, 2 + 7 = 9, 9 − 1 = 8, 8[illegible] 5 = 10[illegible] 4 + 0

5. Ways to reach 0

Direct: 1x23 − 45 − 67 + 89= 0

Reverse: 98 − 76 − 54 + 32x1= 0

Note: A funny but not entirely valid solution (since we did not mention powers) for a) is: 1^{234567} *+ 8 − 9= 0*

Puzzle contributed by:
Dmitrij Nikolenkov (ETH Zurich) | TagesAnzeiger's - Hier trainieren Sie Ihr Hirn | https://www.tagesanzeiger.ch/ (Folgen 317, 374 - 379 des Zahlendrehers)

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Cover photo: Maria Kondratieva, *Les Diablerets*

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The National Centres of Competence in Research (NCCRs) are a funding scheme of the Swiss National Science Foundation