SwissMAP
The Mathematics of Physics
National Centre of Competence in Research

SwissMAP Perspectives

Issue 8 | 2023

Contents

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SWISSMAP ENTERS PHASE III

A year has passed since SwissMAP began its third and final Phase, expected to conclude on June 2026

Phase III Research Directions

The five Phase I & II research projects: Field Theory, Geometry Topology and Physics, Quantum Systems, Statistical Mechanics and String Theory, had numerous contact points and overlaps. The Phase III SwissMAP research has been restructured into six Research Directions in alignment with the goals of this final Phase and of the SwissMAP Research Station. This new structure aims to strengthen the collaborative efforts within SwissMAP.

Differential equations of mathematical physics
Differential equations are an extremely important tool in natural sciences. Since Newton, they have been extensively used to model physical systems and to make predictions about their equilibrium and non-equilibrium properties. At the same time, differential equations define a very active area of mathematics, with a large scientific community working towards the solution of famous and challenging conjectures. It is therefore not surprising that differential equations play an important role in mathematical physics and, in particular, in SwissMAP.

Among the topics studied in this research direction are:

- dynamical system and chaos (ordinary differential equations)
- kinetic theory (Boltzmann equation)
- fluid dynamics (Euler, Navier–Stokes equations)
- quantum mechanics (Schrödinger equation)
- general relativity (Einstein equation)

From field theory to geometry and topology
Quantum field theory (QFT) and mathematical research are closely related to each other. QFT provides new tools for mathematics. A famous example of a connection of quantum field theory with topology is the three-dimensional Chern–Simons theory, whose Wilson loop correlators give the Witten–Reshetikhin–Turaev invariants of knots in 3-manifolds. Many other ideas from physics successfully made their way to mathematics including Feynman graphs and mirror symmetry. Conversely, many developments in geometry and topology have led to progress in QFT.

Among the topics studied in this research direction are:

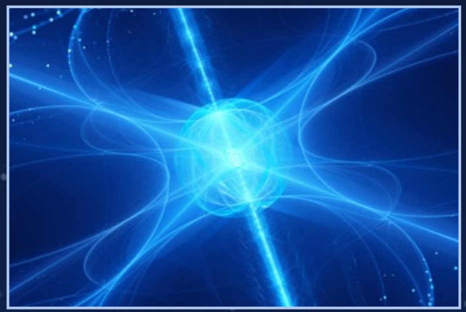
- categorification
- universal knot invariants
- volume conjectures
- applications to rational homotopy theory
- homological methods in field theory
- strings and enumerative problems
- moduli spaces and cycles
- representation theory and non-commutative geometry

Holography and bulk-boundary correspondence
Holographic duality is a research area that plays a major role in developments across the board from string theory and quantum field theory to condensed matter physics. In particular, the AdS/CFT correspondence is a duality conjecturally relating string theory in Anti-de-Sitter space to conformal field theory on its asymptotic conformal boundary. The prototypical case connecting string theory on $AdS^5 \times S^5$ and $N = 4$ supersymmetric Yang-Mills (SYM) theory in 4 dimensions has been extended and applied to many other cases and has been an active field of research for over 20 years.

Recent years have seen a surge of activity on relating simple many-body quantum system to holographically emergent gravity, rich connections to quantum information theory, the conformal bootstrap, as well as renewed efforts to prove holographic dualities in such contexts and beyond.

Among the topics studied in this research direction are:

- proving holography
- holography and integrability
- applications to field theory and conformal bootstrap
- infinite-dimensional symplectic geometry
- bulk-boundary correspondence in condensed matter theory
- non-perturbative effects in field theory and gravity



Quantum information and many body theory
The complexity of quantum many-body systems in general grows exponentially with the number of their parts. This complexity is on the one hand responsible for many interesting physical phenomena, but on the other hand also makes the study of such systems quite challenging. Quantum information theory is a relatively novel approach to analyze these systems and, in particular, to understand the correlations present in them. It also establishes connections to statistical mechanics and thermodynamics, as well as to applications.

Among the topics studied in this research direction are:

- quantum networks
- quantum thermodynamics
- quantum relative entropy
- quantum gases and field theory

Spectral gap problems in non-perturbative quantum theory
Non-perturbative problems of quantum theory with a lacking a small parameter are particularly challenging. Yet, several of the most important physical systems and models are exactly of this type. These include quantum Hall systems, O(N) sigma model, and the 4-dimensional Yang-Mills theory. These are enduring and very complex problems, but any progress achieved in this direction is of great value.

Among the topics studied in this research direction are:

- spectral gap in the fractional quantum Hall effect
- mass gap in spin systems with non-abelian symmetry

Statistical mechanics and random structures
Statistical mechanics describes the typical behavior of macroscopic systems based on knowledge of how their microscopic constituents interact. Many powerful methods and techniques have been developed in order to understand statistical mechanical systems. However, many of these lack a firm mathematical basis and providing a rigorous mathematical framework constitutes a major challenge to mathematicians.

Here we address questions that lie at the interface of probability theory, combinatorics, analysis, and both theoretical and mathematical physics and which contribute to providing a firm mathematical basis for well-established physics methods.

Among the topics studied in this research direction are:

- conformal invariance of lattice models
- random structures in higher dimensions
- conformal growth processes and extremal multi-fractals
- sharp asymptotics of correlations in models with finite correlation length
- asymptotic sphere packing density
- phase coexistence in random graphs

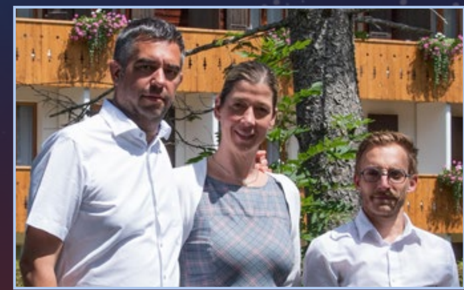
THE SWISSMAP RESEARCH STATION (SRS)

The SwissMAP Research Station, based in Les Diablerets, will not only ensure the sustainability of SwissMAP after Phase III, but it will also provide international visibility as well as continue to encourage collaborations within Switzerland.
This UNIGE and ETH Zurich venture is dedicated to organizing events related to mathematics and theoretical physics (conferences, workshops, thematic meetings) and outreach. Only two and a half years after it opened, there have already been numerous events, including some of international renown, with on-site and online participants from across the globe.

What's new at the SRS?

SRS²
The SRS² program aims to enable small groups of researchers (2-6 people) to work on specific projects for a short period (1 to 3 weeks) within the SwissMAP Research Station facilities. The first edition of the program took place earlier this summer.

Hotel
Hotel Les Sources, home to the Research Station, has a new owner. We thank the previous owner, Patrick Grobéty as well as Stéphane and Alexandra Wartner, the new Managers since June 2023, for their trust. We look forward to our future collaboration.



Stéphane et Alexandra Wartner, Managers; Pierre Browaeys, Assistant Manager

SRS Presentation video
We have prepared a presentation video showcasing the SwissMAP Research Station. The video features several SwissMAP members and is intended to capture the essence of the station. We hope you enjoy it!

SRS Call for proposals 2025
Application deadline: September 30, 2023

https://swissmaprs.ch/

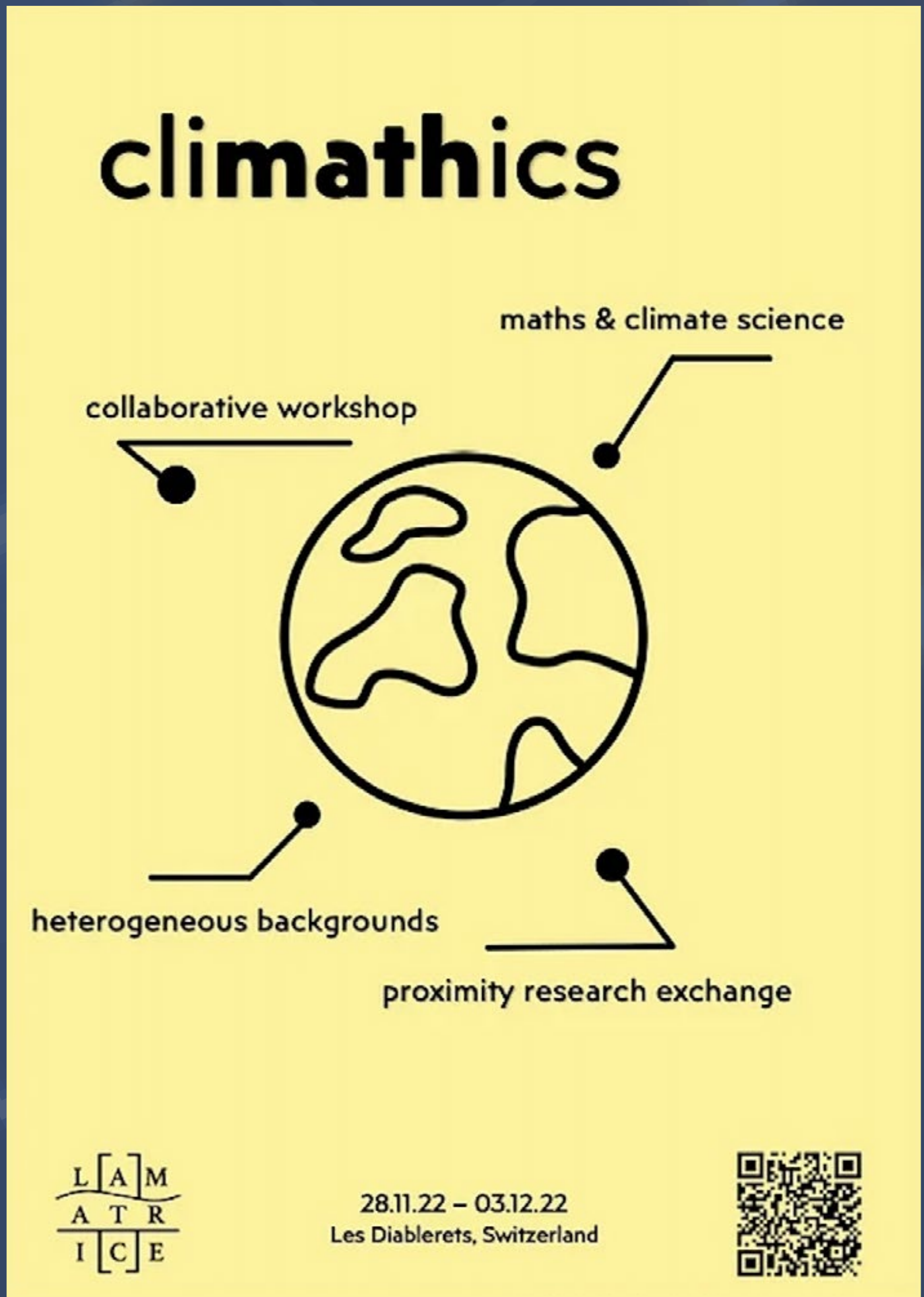
Recordings from several previous conferences are available online.

Subscribe to the SRS mailing list to stay updated with the yearly call for proposals and event programs.

Climathics

The first multidisciplinary conference outside of mathematics and physics at the SRS.

Answers by:
Indira Chatterji (Université Côte d'Azur)
Jeanne Fernandez (EPFL-IMD)
Adélie Garin (EPFL)
Laura Grave de Peralta (UC Louvain)
Alain Valette (Université de Neuchâtel)



What was the initial inspiration behind the conference topic? When was it first proposed?

All the organizers are mathematicians, and wanted to organize an interdisciplinary workshop on climate change and mathematics. We felt concerned and wanted to understand how we, as professional mathematicians, could act on this important issue, as we tend to forget that we are a part of the "real" world. This event was designed for participants to interact and think "out of the box". We wanted to bring the issues related to climate change to an audience of mathematicians who don't necessarily work on questions directly related to climate change and other societal issues.

Climathics was the first multidisciplinary conference outside of mathematics and physics at the SRS. How many different disciplines participated?

While most participants were mathematicians or physicists, we also had people from data science, environmental science, natural science, computer science, sustainable economy, social science and biology (sometimes with several expertise fields).

Research is increasingly moving towards interdisciplinarity. Why would you say it is necessary to deliver solutions to the challenges facing humanity, such as the climate?

The IPCC reports have said it over again: we need to act on climate change. These reports, written by thousands of collaborators from various backgrounds and scientific expertise, are intended as a scientific source for governments to enact climate policies.

And they all agree! It is a moment to join forces, as scientists but also as individuals. We believe mathematicians also have their role to play. As Grothendieck said "*Fight for the survival of the human race and for all life, which is endangered due to the ecological imbalance caused by the industrial society of today (pollution and destruction of the environment and natural resources), and by military conflicts and the threat of military conflict.*"

The world is changing too fast for science to fully keep track; it becomes more and more necessary to be creative, resilient and develop complex thinking, qualities that we believe are best developed in groups with different perspectives and backgrounds.

The agenda also included activities that went beyond the exchange of information on recent advances.

In the absence of a common language did you come across limitations in terms of research, methodologies/expectations?

Most of the time, the differences between our respective backgrounds turned out to be more a strength than a weakness in the discussions.

Most people had a good background in mathematics, even the ones who were not mathematicians.

We also designed the program of the workshop to try to avoid as best we could limitations in that regard. The goal of the workshop was that all participants could interact with each other. For each main talk, we organized follow-up group work sessions and had moderators who were specialists on the main topics.

We did so to provide a space where the participants could ask questions and discuss their opinions. Thus, limiting the problems regarding methodology or expectations.

What would you say are the skills required for successful cross-disciplinary collaboration?

Willingness and enthusiasm are key. All the participants were so eager to learn and all the speakers so willing to share their knowledge and expertise. All that remained was to provide a fantastic setting such as the Swissmap Research Station and enough time for discussion and exchange!

"Fight for the survival of the human race and for all life, which is endangered due to the ecological imbalance caused by the industrial society of today (pollution and destruction of the environment and natural resources), and by military conflicts and the threat of military conflict."

What were the conference's results and conclusions?

After the workshop we surveyed the participants for some feedback on the event. To start with a singular, non-academic result, most participants mentioned that they are willing to reduce their meat consumption and/or their plane-travel following the discussions of the workshop (and a vegetarian week at the hotel).

A concrete project that emerged from the workshop was to create a "sustainability label". The idea would be to show to other scientists our interest regarding climate change via a logo on our slides for example. An invitation to discuss and a visible marker of our commitment as individuals.
We also hold weekly meetings on Thursday morning to create math problems with themes related to the climate crisis. The working group is open to everyone willing to join! Contact the organizers if you wish to join us.

What are the next steps?

A book. This workshop inspired a few organizers and participants to write a book intended for mathematicians willing to incorporate sustainability into their lectures.And maybe a Climathics 2.0 in 2024!

Can you tell us about your experience of the SRS as a conference venue?

The setting of the SRS was ideal for our workshop. The size of the rooms allowed us to organize group sessions and other activities (such as a Climate Fresk). Being surrounded by those amazing mountains was a huge plus!

And the hotel management was very flexible, allowing us to have a fully vegetarian week.

This workshop inspired a few organizers and participants to write a book intended for mathematicians willing to incorporate sustainability into their lectures.

Carbon footprint & linear algebra
Article by Elise Raphael

As mentioned in the interview, one of the next steps is to provide content to mathematicians to incorporate sustainability topics into their lectures. For example, linear algebra shows up in carbon footprint computations...

Many of us have once tried a carbon footprint calculator, such as WWF's. While the results are always a good incentive to try to change our lifestyle, it does make one curious about where these numbers come from.

It is indeed quite hard to find the details of the computations and data involved in computing carbon emissions.

One surprisingly recent method, called extended input-output analysis, comes from economy and uses some basic linear algebra to track quantitatively the carbon emissions associated with a purchase (called consumption-based emissions).

Full article available on the news section of the SwissMAP website

All images from the Climathics Conference Nov 28 - Dec 3 2022.

SwissMAP contributed significantly to maths outreach over Phase I & II and will continue to have a substantial impact on a national and international scale during Phase III.

National OUTREACH Activities

2023 Highlights from our out-of-school learning structures

Junior Euler Society (UZH)

Approximately 350 schoolchildren participate every year in the Junior Euler Society (JES) directed by Anna Beliakova and Tatiana Samrowski. This year 46 JES participants won medals, including gold, silver and bronze, at various national and international Math Competitions.

The Prize Award Ceremony took place at UZH Campus Irchel on June 26, 2023.

Credit: Junior Euler Society (UZH): Prize award ceremony 2023

Math Youth Academy (ETH Zurich)

The ETH Math Youth Academy was established on a permanent basis at ETH Zurich and Kaloyan Slavov was appointed as its head.

Some participants shared their experiences:

"It was at the ETH Math Youth Academy where I really developed a joy for mathematics."

"Attending strengthened my decision to study mathematics at ETH. We discussed very interesting topics, and I learned how to structure mathematical arguments."

"I had no idea how much more maths had to offer beyond what we were taught in school, so when I heard about Math Youth Academy at ETH, I decided to visit once out of curiosity. It immediately sparked my interest, and during the year and a half I participated, my passion for problem solving skyrocketed."

ETH Math Youth Academy Playlist is available on our YouTube channel.

Credit: Scienscope-Exploratis

Mathscope (UNIGE)

Mathscope now shares a newly renovated dedicated space with other UNIGE Scienscope labs.

Exploratis

The Scienscope now hosts Exploratis, an installation which consists of two iPads and a large screen and is based on reconfiguration puzzles arising from ideas in geometry and topology. Players attempt to reconfigure puzzles while the graph of possible states is slowly revealed on the big screen. A player can play individually, race against someone else or collaborate with another person to find a common configuration.

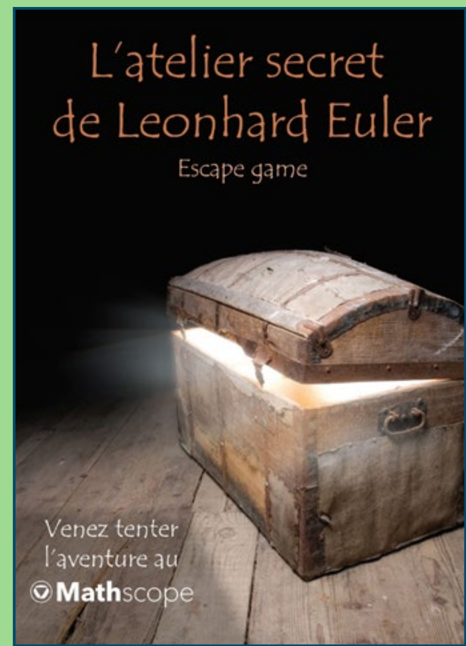
Exploratis was developed in conjunction with the Luxembourg Science Center and was showcased at the Luxembourg pavillion at World Expo 2020 in Dubai.

The team behind this project (on the math side: Hugo Parlier and former SwissMAP science writer, Paul Turner; and on the development side: Mario Gutiérrez and Reyna Juárez) have created a free app, Quadratis, with a selection of puzzles to be played on a smart phone.

For more information on Exploratis:

Escape Game

A new mathematical escape room, Leonhard Euler's secret workshop - has been installed. Created with the support of the Swiss Mathematical Society, this is an activity for groups of 3-6 adults or children from the age of 12.



Credit: Mathscope Escape Game

Credit: "Les Marmottes Filles et Maths", April 2023

Les Marmottes

The first edition of "Les Marmottes Filles et Maths" successfully took place at the SwissMAP Research Station in April 2023.

The program is inspired by the CIRM's "Les cigales".
This one-week-long workshop, organized by Sandie Moody and Elise Raphael, aims to initiate high school girls to what it means to do research in mathematics.

Watch the Marmottes Filles et Maths presentation Video on our YouTube channel

Upcoming: Italo Calvino Exhibition

Among the best-known Italian authors, Italo Calvino has significantly contributed to twentieth-century culture. In 2023, we celebrate the 100th anniversary of his birth. To mark the occasion, Francesca Serra from the Italian Department and Shaula Fiorelli from Scienscope at the University of Geneva have joined forces with the Maison Rousseau et Littérature's support to pay tribute to Calvino.

The exhibition will take place in Geneva from 13th of September to 5th of November 2023 and will be, first and foremost, a journey. A journey through science and literature as instruments of knowledge that continually intersect and intertwine. A journey that will take you on a discovery of how these two complementary worlds can interact thanks to the powers of writing and the importance of imagination. You will be invited to observe, touch, experiment and write.

International OUTREACH Activities

Let's Talk about Outreach & Math'émerveille

The "Let's Talk about Outreach" conference took place in October 2022. It brought together over 50 participants from Switzerland, France, Germany, the United Kingdom, the USA and Algeria and from various backgrounds: museums and science centres (MoMath in New York, Palais de la Découverte in Paris, Maison des Maths et de l'Informatique in Lyon), universities, and mathematics promotion associations.

Four activities were developed entirely and finalized during the workshops: "Devil's square", "Magic polyhedra", "Stacking spheres" and "What is the question?". These activities were presented at the following festival Math'émerveille and will be published on the CNRS Image des Maths website for wide distribution.

Videos of the conference and a series of five interviews are available on our YouTube channel

"Let's Talk About Outreach", October 2022. Credit: Bertrand Paris-Romaskevich

Upcoming: Matrix X Imaginary 2024

We are glad to announce that the SwissMAP Research Station will host the international conference Matrix X Imaginary 2024.

Organizing committee:
- Shaula Fiorelli (SwissMAP)
- Cindy Lawrence (MoMath)
- Andreas Matt (IMAGINARY)
- Elise Raphael (SwissMAP)

Written by Mayra Lirot
2023, Geneva

A conversation with Hugo Duminil-Copin

Born in 1985, Hugo Duminil-Copin grew up in the Paris region. He graduated from the University of Paris-Saclay. Appointed professor at the University of Geneva in 2013, he is also a permanent professor at IHES in Bures-Sur-Yvette since 2016.

His work focuses on the mathematical branch of statistical physics. He studies phase transitions using probability theory.

Hugo was awarded the 2022 Fields Medal for his work in statistical physics.

Since receiving the Fields Medal, how has your work schedule changed?

It has changed a lot. Mainly, because of public appearances and the media. This takes up a lot of my time, but it is very interesting. And it forced me to change how I was doing other things. I write less for instance, but I try to draw a line, so I still teach. Teaching gives me some regularity in what I do. I was also very careful to define a clear schedule between work and time with my family. I work from 8am to 6pm, only during the week. The rest of the time, I am not reachable. This has helped me a lot to not overdo it.

What responsibilities come with the Fields Medal as an ambassador of the discipline to society? Any anecdotes?

This is truly the biggest change. In France, in particular, there is a lot of incentive to talk to the public and to children. I give a lot of talks in high schools and secondary schools. This is quite interesting, because we are facing a time when science is often questioned, as we have seen during the pandemic. A lot of people have a false vision, not of science, but definitely of research, meaning the process to get to knowledge. I believe it is crucial to make an effort and use the visibility the Fields Medal gives. It is important to talk to the public and explain that the reality is slightly different to what they think.

What are the ways the Fields Medal has been a significant contributor in terms of your efforts to popularize mathematics?

The most significant is that you are contacted by people who would not contact you otherwise. For example, the Ministry of Education in France would probably not think to contact me before the Fields Medal. But now that we are in contact, we can develop ways to optimise and favour mathematics, and science in general, in schools.

Your media presence also changes a lot. When you do mediation and science popularisation, there is one thing you quickly realise: that you always reach the same people. This is something I found out well before the Fields Medal. You will attract people who know that there will be a talk and want to come to it. But this is only a tiny proportion of people and probably not the ones that need to hear about science the most. These are usually people who are already linked to science in some way. But the Fields Medal opens a door to the media. You can be invited on TV and reach a much wider audience. This is definitely something that the Fields Medal helps with, and I think it's good that it exists for this reason.

Would you like to develop this further in the future?

Yes, I do, and it is important to find out how you can be useful. This depends a lot on the person. Some people are very gifted in organising the politics of our community. There are people who can have certain responsibilities like running a university or doing editorship. I'm not very gifted in these things and it scares me a lot. I'm more comfortable in talking to people about science or trying to give a good impression of what a mathematician or scientist can be. Maybe because I was never an amazing student in mathematics, so I feel closer to the average student who doesn't have a special gift in mathematics. For this reason, I'm comfortable telling a kid it's too early to know whether you're going to be a mathematician or not. I would tell them to just enjoy life and do many different things. This is something I feel comfortable with and want to develop further. I don't know whether it is useful, but it's in line with what I think, which is the most important.

> There is in fact no connection between whether you are a great mathematician, and whether you should enjoy mathematics.

In a recent interview you said: "*In fact, maths has probably everything to become the perfect hobby: critical thinking, problem-solving, interesting stories, links to other fields of science, historical relevance, etc. The important catch is to adapt the level to the audience.*"

Yet, arguably maths is perceived as one of the least favourite school subjects. How could the mathematical community help more people perceive maths as a hobby?

This is a big discrepancy in mathematics nowadays. We have difficulties separating mathematics from school. People are starting to understand this, but it is still a slow process. If people love French, or English, it is not because they love dictations or grammar. They love it because they love reading. And they do that outside of school. This is the goal that we should try to reach for as mathematicians. We need to offer other ways of doing mathematics, in the form of recreational mathematics. Of course, this already exists, and we know people who develop this. But it is still very under-developed compared to other subjects, like astronomy. And I believe that the professional mathematician also has a responsibility in this. It is important that each one of us tries to find ways to help develop this other way of seeing maths. And, to help the people who do this professionally. There are more and more people who do popular science for a living. They would benefit from our ideas. I remember talking with the organisers of MoMath, and they had many interactions with mathematicians who gave them ideas on how to do things which then led to a certain exhibition. There is almost systematically some input from a mathematician behind most of these events. So, I believe it is important that we all feel responsible, and help others to create events and acknowledge that it is a real job to develop tools for popular science.

What do you answer to the (probably numerous) people who tell you "I've always been terrible at maths"?

First of all, these people are often not actually terrible at maths. When you talk to them some more, it usually turns out they had an average score. And average is not terrible. Their perception is that of being a failure in math, which is often very disconnected from their actual level. What I will usually tell them, is that I do a lot of sports, but I'm terrible at it. Or average, to make the same analogy. But I still enjoy it. Many people enjoy running but are terrible at running. There is in fact no connection between whether you are a great mathematician, and whether you should enjoy mathematics. I always ask these people to think back to a moment when they enjoyed math. And it is these moments that you want to be recreating. When you do this systematically, and take pleasure in math, then you will progress. If you don't have any pleasure, and lack the discipline, you won't. For children, if we can disconnect this notion of levels, we can help them enjoy maths and become good at it. Progress takes time, but if they enjoy it, they will take the time to become better.

What is the post Fields medal request or contact that surprised you the most?

There were quite a few and some will remain private. But one of the surprising ones I can talk about is when I was contacted by a French radio show. In France, there is a popular and quite coarse show called "Les Grosses Têtes". It is not a place you would imagine seeing a Fields medallist. And this show contacted me to become part of the group of people who appear in it regularly. Of course, this would reach a population that I don't usually talk to, but I thought it would be too much. The mathematician in me decided to decline. But there is another part of me that loves to make bad jokes that are not that funny. And this part of me thought it would be a great thing to try. But in the end, I declined the request because it would be too far from my comfort zone.

What do you most enjoy about teaching?

For me, it is definitely transmission. As soon as I have an idea, the first thing I want to do is to share it with somebody around me. So long as I don't transmit ideas or concepts, I am not truly happy. I love to teach because it is part of the transmission of knowledge. This is very important to me. During my career, there were times when I had the possibility to not teach anymore. But I always came back to teaching fairly quickly.

Credit: UNIGE - © Fabien Scotti

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

It's very difficult as it depends very much on the person. I usually talk to the student first, to understand what they are doing and how they see mathematics. Because it is better to give advice to counteract a little bit with what the person is doing. To give them other tools. It is not easy to give advice without further information. But some general advice I could give, is to have several projects of different levels, happening at the same time. At least three projects. The first one should be quite easy, safe, and that you know you will solve. The second project should be something in the middle. And the third, is a project that you can think about from time to time and only hope to make some progress on it. This allows you to have a balance because your brain is ready for different types of thinking at different times. In the morning for instance, I like to do automatic things and I'm very focused. In the afternoon however, my brain overheats and it's important for me to be able to think about projects that are more relaxing. Having multiple problems with different layers of difficulty allows you to switch from one to the other. They also bring you different results. Usually, very big problems allow you to learn new things.

Can you tell us about the research project "*Emerging symmetries in critical systems of statistical physics*" for which you recently obtained an SNSF Consolidator grant?

I like this project because it comes as a continuation of the program I initiated when I was a PhD student. I wanted to study dependent percolation models that were not well understood at the time. There are several steps to this process. When you try to study a statistical physics problem, you want to understand the phase transitions and the changes of behaviour in the system. First, you want to locate where this transition occurs, then you focus in on this. It took me 10 years to understand how to compute the critical point of something. And 5 years ago, I reached a stage where I started focusing on what is qualitatively happening exactly at the point where you have the phase transition. This is something we understand quite well now. The next step is to study the quantitative, very precise, and delicate properties of what happens during the phase transition. These properties are called emergent. Among these emerging properties, I would like to understand what we call invariances, and more specifically, conformal invariance. They appear only at the critical point. For example, they will only appear at 100°C for water and not above, nor below (though that's not a very good example, especially in physics). And so, this program for which I received the SNSF Consolidator Grant happened because I feel I reached a point in my research where these questions have become within reach. They are not easy, but they are within reach and I'm very excited and progressing well in this direction.

> Having multiple problems with different layers of difficulty, allows you to switch from one to the other. They also bring you different results.

Outside research who is the person you admire the most?

In popular talks, particularly to kids, I often mention the football player Mbappé. Because to me, this is a great example of someone who is excellent in his field, there is no question about it. But he is also a good example for the children. Maybe in sports, it is easier than in science, but I believe it is not easy to be a good inspiration for our youth. It is, however, important. So, I admire this person who was able to have such maturity starting from a young age. I find him very inspiring.

Which is your favourite book or movie? Any hobbies?

I am a big fan of the Marvel movies! Every time I'm giving an interview, and the personal questions come up, everyone thinks I must like very smart movies. But no, I like Marvel and have watched all of them at least five times. I can sense that my brain loves it because it can just relax and enjoy the moment.

In terms of books, I don't read that much outside of math. My wife and I have the same problem, that we read so much for our jobs, we don't read a lot in our spare time even though we both love to read. She's a French teacher, so it's even more ironic in her case. This year, I have tried to read more books outside of my scientific reading. I have been able to read multiple books about mathematics and about how you see mathematics. I really recommend the French book by David Bessis called Mathematica. This author has put a great vision of mathematics into words, and I think it would be a very interesting read for mathematicians. It discusses intuition in mathematics and how it has developed over time. When I was younger, I read a lot of fantasy, like J.R. R. Tolkien and David Eddings. But I don't read these types of books anymore. There are other priorities in my life and reading is unfortunately below many of them.

As for my hobbies, I used to do a lot of sports. I used to do many things like climbing, volleyball or running, and this I miss a lot. I don't do sports that much anymore, not because of the Fields Medal, but because of my daughter. When I'm not working, I want to be with her. The first thing I do after work, is bike or drive back home.

Conversation with Hugo Duminil-Copin
Geneva/Online

Interviewed by Maria Kondratieva
On behalf of NCCR SwissMAP

Mikaela Iacobelli

Chiara Saffirio

The Swiss Kinetic Theory Community

There has been a great deal of interest in kinetic theory in recent years. Almost two years ago, our members Mikaela Iacobelli (ETH Zurich) and Chiara Saffirio (UniBAS) started the Kinetic Theory Seminars to strengthen and consolidate the kinetic theory community within Switzerland.

Swiss Kinetic Theory Seminar 2023, ETH Zurich

The seminars take place twice a year, usually in November and May. They are informal and designed to facilitate the interaction between speakers and participants and promote collaborations.

Despite the initial difficulties under COVID, from the beginning, it has successfully brought together participants and speakers, mainly from Switzerland, but also from other countries. This international dimension has also benefited the Swiss Kinetic Theory Community. As a result of the seminars, some fruitful scientific discussions have already taken place between participants from different institutions.

The seminars alternate between the ETH Zurich and the University of Basel and usually last two hours, with the first hour introducing a topic and the second hour focusing on recent results.

The most recent Kinetic Theory Seminar earlier this year was held at ETH Zurich, and it celebrated women's achievements as part of the May12 initiative. The event was also listed on the May12 website. Two renowned women speakers, Prof. Giada Basile (Sapienza University of Rome) and Dr Megan Griffin-Pickering (UCL), were invited to the event.

Swiss Kinetic Theory Seminar 2023, ETH Zurich

Basel will host the next seminar in autumn 2023. Everyone interested in participating is welcome to register.

Swiss Kinetic Theory Seminar 2023, ETH Zurich

The seminars are announced through the SwissMAP website.

2022 SwissMAP Innovator Prize winners

Barbara Dembin
Summary of research work on percolation models

My research mainly focuses on percolation models, which aim to study the connectivity properties of random sets, as well as the study of geodesics in random metric spaces. To provide insight into my research, I will present two recent results.

In collaboration with Vincent Tassion [5], we studied Boolean percolation, a percolation model that is parameterized by two parameters: a radius distribution μ and an intensity λ. We consider a Poisson point process of intensity $\lambda \in \mathbb{R}$ in $\mathbb{R}^d$ (which is a process of random points in $\mathbb{R}^d$ such that the average number of points in a cube of volume 1 is given by the intensity λ and the number of points in disjoint regions is independent). On top of each of these points, we independently center a ball of random radius distributed according to μ.

The main question of interest is the existence of an infinite connected component of balls, which depends on the parameter λ. Due to monotonicity in λ, the larger the value of λ, the more likely it is to have an infinite connected component. We can prove the existence of a critical parameter $\lambda_c(\mu)$ such that the model exhibits a phase transition at this parameter (see Figure 1). For $\lambda < \lambda_c(\mu)$, there is no infinite connected component, whereas for $\lambda > \lambda_c(\mu)$, there exists a connected component (which we can prove is unique).

Our goal was to prove "subcritical sharpness", that is to obtain a quantitative control of the typical size of finite connected components in the subcritical regime $\lambda < \lambda_c(\mu)$. When μ is compactly supported, this can be solved using standard methods from percolation theory. However, when μ is unbounded, it induces long-range dependency. Duminil-Copin–Raoufi–Tassion [6] previously proved subcritical sharpness for distributions μ with sufficiently light tails. Vincent Tassion and I managed to prove subcritical sharpness for "almost all distributions" by introducing an extra degree of freedom through parametrized families of μ.

Together with Dor Elboim and Ron Peled, we studied geodesics in the model of first passage percolation in [4]. The First-Passage Percolation model was introduced by Hammersley and Welsh in 1965 to model the spread of fluid in a porous medium.

In this model, each edge is assigned independently a positive random variable distributed according to some distribution *G*, interpreted as the time required to traverse the edge. One can then define a random pseudo-metric *T*, where *T(x,y)* represents the time of the shortest path connecting *x* and *y* in terms of the assigned passage times. The geodesics correspond to the time minimizing paths for this pseudo-metric.

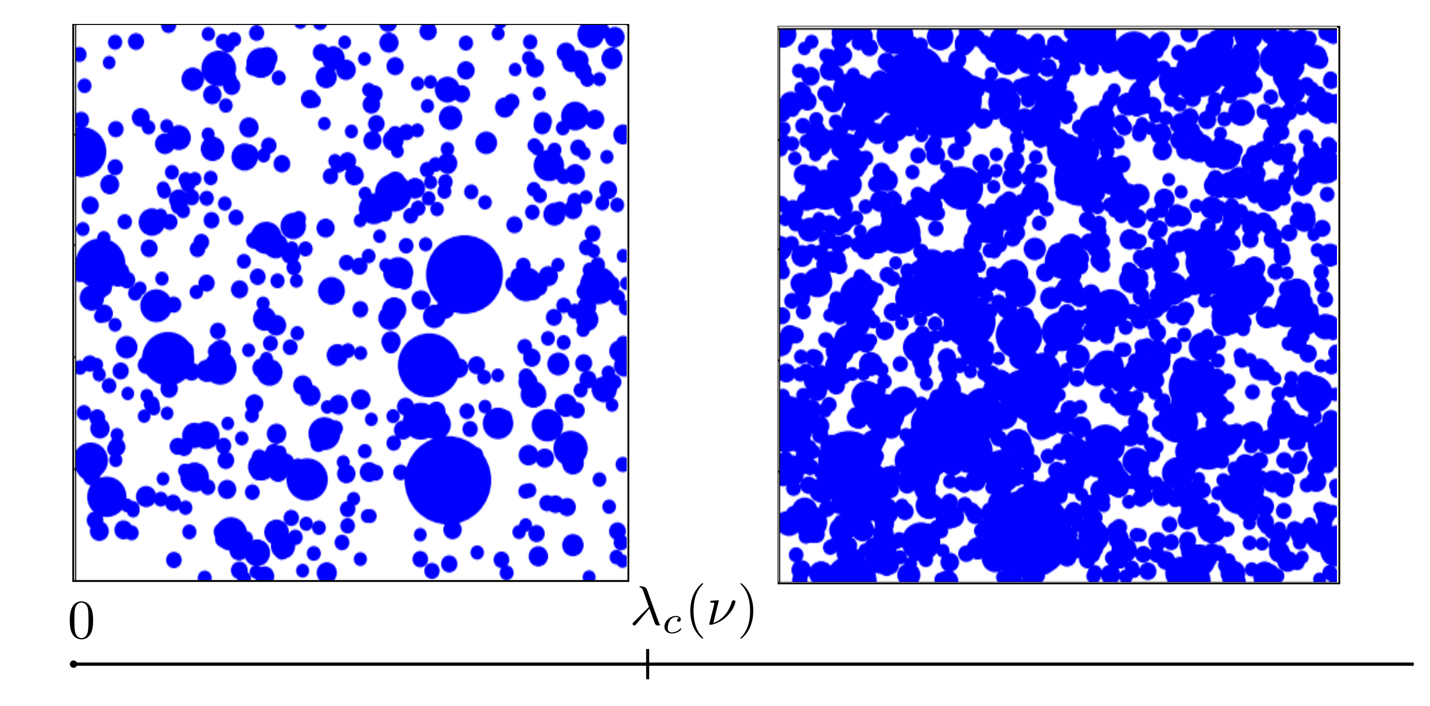


Figure 1. Phase transition for Boolean percolation.

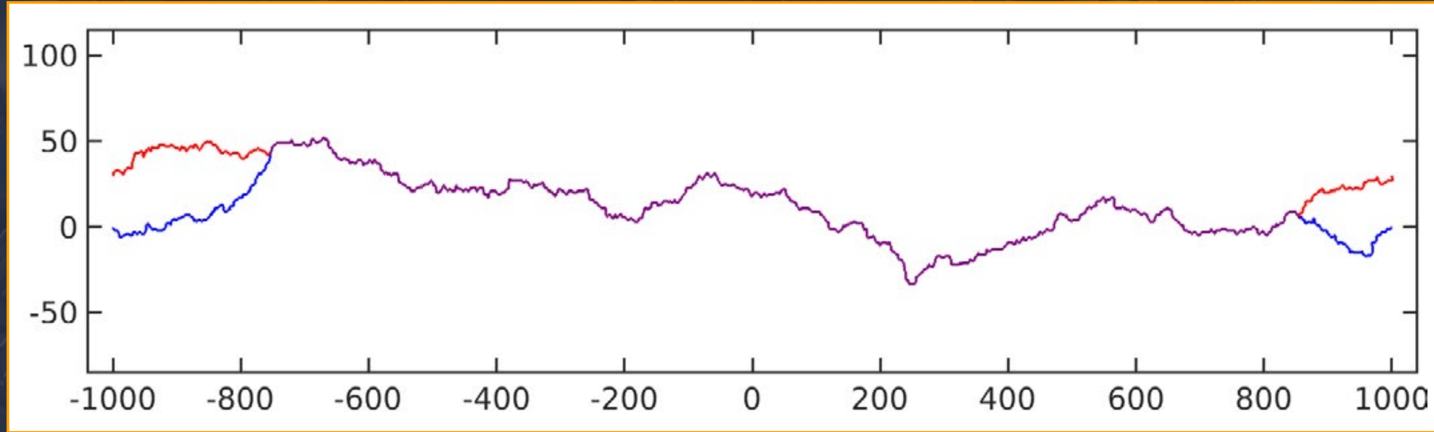


Figure 2. Simulation of two coalescing geodesics with close starting and ending points. Simulation of Dor Elboim.

Let us consider two geodesics γ_1 and γ_2 whose starting and ending points are very close compared to the total length of the geodesics. We say that the geodesics *coalesce* if $\gamma_1 \cap \gamma_2 \neq \emptyset$. In other words, these two geodesics will use the same "highway" to reach their destination (see Figure 2). The closer the starting and ending points are, the more likely this scenario is, and the larger the common portion of the path.

Our key result is to show that with a very high probability, two geodesics γ_0, γ_1 that remain close must merge (proved in any dimension). To use the highway analogy again, two parallel highways cannot coexist if they are close to each other.

Benjamini-Kalai-Schramm (BKS) [2] introduced the midpoint problem: does the probability that *0* is in the geodesic between (-*n*; *0*) and (*n*; *0*) tend to *0* as *n* tends to infinity. This question was resolved by Damron-Hanson [3] and Ahlberg-Hoffman [1] non-quantitatively in dimension 2. A consequence of our coalescence result is a quantitative resolution of the midpoint problem of BKS in dimension 2: the probability decays polynomialy fast to *0*.

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[4] Barbara Dembin, Dor Elboim, and Ron Peled. Coalescence of geodesics and the BKS midpoint problem in planar first-passage percolation, 2022.

[5] Barbara Dembin and Vincent Tassion. Almost sharp sharpness for Poisson Boolean percolation, 2022.

[6] Hugo Duminil-Copin, Aran Raoufi, and Vincent Tassion. Subcritical phase of *d*-dimensional Poisson–Boolean percolation and its vacant set. *Annales Henri Lebesgue*, 3:677–700, 2020.

Author: Barbara Dembin
ETH Zurich, V. Tassion's Group

2022 SwissMAP Innovator Prize winners

Tomas Reis

The Strange Quantum Vacuum or how I Learned to Stop Worrying and Love Divergent Series

The current model of fundamental physics is that almost everything is a fluctuation of quantum fields. With the exception of gravity, all known particles and forces are described by the fields of the Standard Model. This is a tremendous scientific triumph, but there are some caveats. One of them is that calculations in Quantum Field Theory (QFT) are really hard.

The way that physicists usually approach a quantum field is through the technique of Feynman diagrams. These are drawings which *are* calculations. I do not mean that the drawing illustrates a calculation. The process of drawing the diagrams is itself a step of the calculation. Of course, there are complicated integrals afterwards.

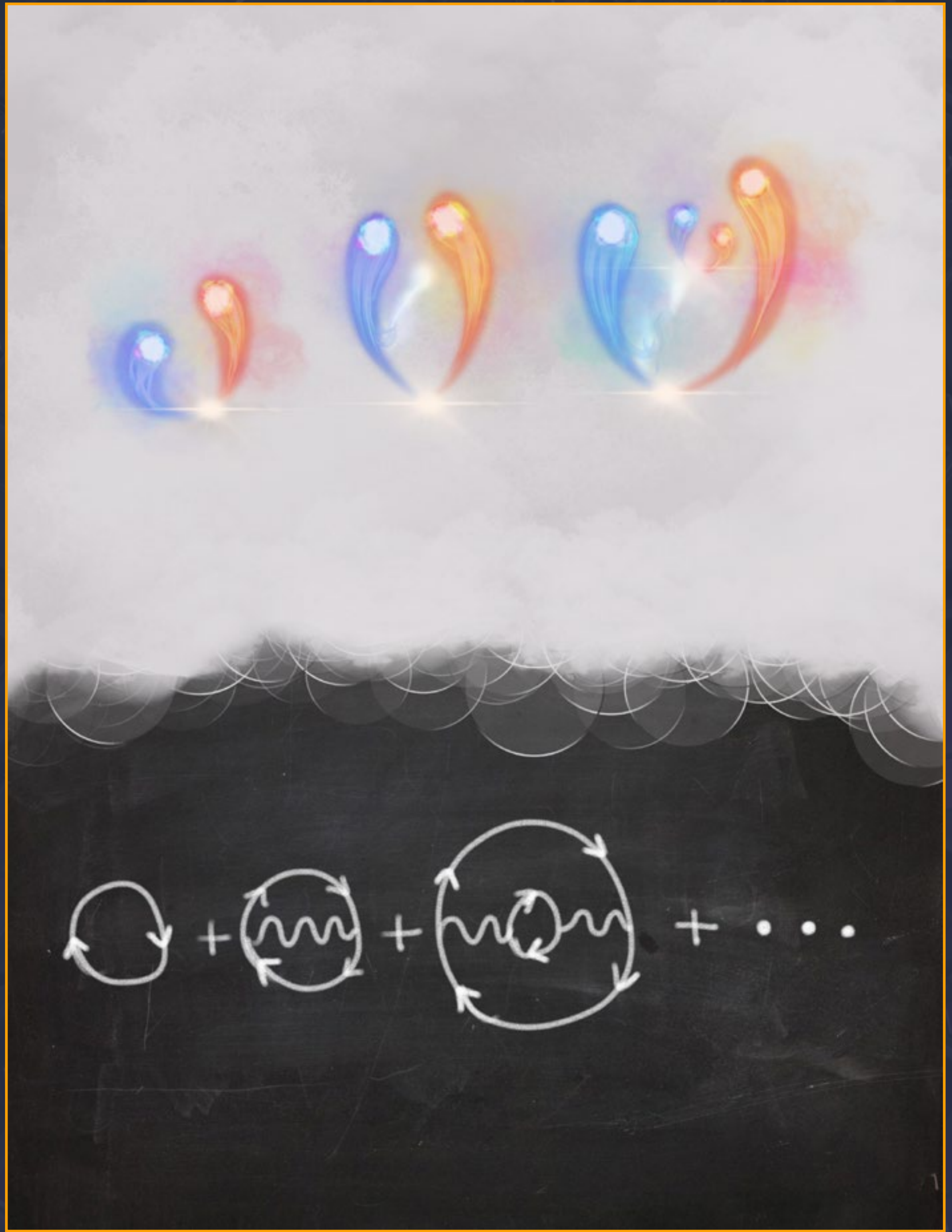


Figure 1. Summing up the possible fluctuations of the vacuum. Credit: Tomas Reis

To illustrate the logic behind Feynman diagrams, let's think about electrons and imagine they only interact with the electromagnetic field, whose particle is the photon, and nothing else. One calculation that is important in physics is the energy of the vacuum. This is interesting because in QFT the vacuum is not empty. The field is always there, and then particles are just persistent perturbations on top of it. So even in the absence of particles, there can be quantum oscillations of the field itself.

To calculate this energy, we must draw diagrams for each of the possible fluctuations of the vacuum. So maybe an electron and an anti-electron, a positron, appear out of nowhere, move a little bit, and collapse together in total annihilation. But, maybe, the electron emits a photon, the positron absorbs the photon, and only then they annihilate. As long as we start with nothing and end with nothing, like in our own mortal existence, it's a valid diagram. One could have the electron and positron appearing, the electron emitting a photon, this photon decaying into a new electron and positron pair, the new pair annihilating into a new photon, only for the first positron to absorb the new photon and then to annihilate itself with the original electron. Dust to dust, ashes to ashes, vacuum of the quantum field to vacuum of the quantum field. In the end, quantum mechanics tells us to sum all of these possibilities. [Fig. 1]

This might seem messy, but, if we assume that the electron charge is small, each time the electron emits a photon the situation becomes quantum mechanically less likely. Thus, the pair exchanging a single photon is somewhat probable, but the telenovela-worthy plot of photons turning into electrons turning into photons is much more unlikely. We can organise the diagrams by how many photons are emitted, so that we sum first all the diagrams with one photon, then two and so forth. We are left with summing the resulting infinite sequence, a *series*.

While one can easily sum infinite but increasingly small numbers, in quantum field theory the numbers are not increasingly small. The first few are, which allow us to make experimental approximations. In fact, these approximations are so good that some measured properties of the electron match theoretical predictions with the same accuracy as guessing the volume of Lac Leman to the precision of a gallon of Swiss milk. However, if we consider diagrams with many photons, at some point they start becoming very large, the series becomes *divergent*.

Fortunately, there is a mathematical framework to handle divergent series, the theory of *resurgence*. It is called the theory of resurgence because when summing these divergent series you discover that there are physical properties which are not captured by the diagram prescription. These are called "non-perturbative physics", and they "resurge" in these series. One example of "non-perturbative physics" is a soliton, which is basically a tsunami in a quantum field if we think of regular quantum fluctuations as the surface waves.

In my PhD with Professor Marcos Mariño, I studied a class of "non-perturbative physics" called renormalons. Theoretical physicists are not sure what these are, but they leave their mathematical imprint in divergent series. There was an important conjecture about their mathematical structure, sketched by two Nobel prize winners: Giorgio Parisi and Gerardus 't Hooft. We, me and my supervisor as well as postdoc Ramon Miravitllas, focused on integrable field theories. These are very special theories where, among other things, particles only move in one spatial dimension in addition to time. They allow us to tremendously simplify the equations and obtain exact results without the diagrams. We ended up finding renormalons which do not obey the conjecture, which is exciting. However, this left us with more questions than we started with. Then again, that's the fun of it.

Author: Tomas Reis
UNIGE, M. Mariño's Group

Alumni Corner

Arthur JACOT

(Courant Institute of Mathematical Sciences, NYU)

Arthur Jacot studies deep neural networks and other related statistical models to develop a deep learning theory. He completed his Master's and PhD at EPFL under the supervision of Clément Hongler. In 2021 he received the SwissMAP Innovator Prize for his works in the study of large-scale Artificial Neural Networks, particularly via the introduction of the Neural Tangent Kernel, and for his works on Random Feature and Kernel models using random matrix techniques.

In 2022 Arthur transitioned from PhD to a tenure-track Assistant Professor position at the Courant Institute of Mathematical Sciences, NYU in the Maths department.

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.

What's your favourite part about being a mathematician or maths in general?

I always wanted to do creative work. I had a hard time choosing between music, art, and maths. However, many things worked well for me in maths, so I chose maths and I am very happy with this choice.

Can you briefly explain your research?

The problem I am trying to solve is around artificial neural networks used for artificial intelligence. Even though they work exceptionally well, the question remains on how they operate. We are talking about huge models with many neurons, and we don't know what the neurons in the middle of the network learn, in the same way that we don't understand the brain, even though it works.

As a result, a new approach has been devised following the idea that, much like in theoretical physics, one can study limits when the number of particles goes to Infinity. Similar tools can be used to understand a neural network, as it is challenging to understand a neural network with billions of neurons. It's simpler to think of it as almost an infinite amount of neurons and try to approximate it in this infinite neuron limit.

Something we realized, and in some sense, this first work on NTK (Neural Tangent Kernel) led to this realization, is that there are many different regimes where the networks behave very differently. The NTK exhibited one specific limit, where everything simplifies because there are so many neurons, it's sufficient for each neuron to change just a little bit during the training phase, and everything moves even if it is just slightly. However, because there are so many of them, it still affects the final output neurons, allowing them to learn, for example, to activate if there is a dog or a cat in the image and recognize objects. It is sufficient to move everything very little and to still learn.

As a result, the nonlinear dynamics of a neural network training can be linearized, leading to very simple training dynamics. Of course, proving that you can make this simple approximation is a lot of work, but you end up with something very simple. In the last few years, several results have shown how this limit's simplicity is also its weakness because it doesn't capture some properties that interest us in the networks. For example, the way neural networks learn representation, translating the inputs into a learned conceptual space. We know that in this NTK limit, these representations remain fixed, so you don't see the evolution, the way the network learns representations.

In other words, as neurons move very little, they have the same representation as before, and you have this random initialization where the representations are random, not learned. And so because this representation stays the same in the NTK image, there's no learning of the representations.

But there are also so-called active regimes that are much less understood at the moment. In many cases, these regimes are identified by starting from the NTK regime, and trying to break it, to see how if we change a specific parameter of the model, the linearization stops working, and you end up in very different regimes. But we still need a full map of how these regimes are related or connected in some sense.

What I am currently working on is developing tools to understand these active regimes, some tools that work across different regimes and some conceptual ideas that are useful there. Even if the dynamics can be quite different in these regimes, in the end, the kind of representation learnt has some similarities, such as feature learning and sparsity. In my recent work, I have started describing how networks with a large number of layers learn representations in one specific active regime. In this setting, the main goal of the network is to compress the input information while keeping enough information to map back to the outputs.

Arthur Jacot receiving the SwissMAP Innovator Prize 2022. Credit: Julien Gaspoz Photographe

AGM 2022. Credit: Julien Gaspoz Photographe

More precisely the network tries to reduce the dimension of the representation of the inputs to the smallest dimension that still allows the model to fit the data. And this leads to a notion of rank over non-linear functions, the Bottleneck rank.

For example, for images, the dimensionality of the inputs is the number of pixels which is enormous, and somehow the neural network, in several different ways, can find very low-rank representation of this data. This is very useful because once you have a low-rank representation, you're able to avoid the well-known curse of dimensionality in statistics. It's very difficult to learn things in high dimensions as there is a high dimensional geometry property where every point is roughly the same distance. Roughly speaking, a lot of statistical models work in this way: say you have received lots of images of cats and dogs. If all the cats are in some region and the dogs are in another region of the space, and if I get a new image, I try to look at whether it's closer to the group of cats or dogs. In high dimension, the problem is that everything is at the same distance, so it's complicated to say whether you're closer to one or the other group. It appears that neural networks are able to learn and take advantage of low-dimensional representations to avoid this curse of dimensionality, since the classification is done in this low dimensional space.

Of course, the question is, "How does the network choose this representation?" There's some compression where it loses lots of information to compress everything to a lower dimension. And exactly why? How much of the information is lost? How much is conserved? And so there are still many open questions. But now, my last work was at least describing this bias toward finding this low-dimensional representation.

How did you come across this topic of research?
I've always been very interested in music, and when I saw these neural networks could generate images and so on, I wondered how they could be used to generate music. I tried to make it work, but then I realized how even small changes to these models could break everything. It is complicated to train them because even minor changes in hyperparameters, the way you initialize and train the network, can completely break the model. That is when I realised that there was a lot of important work to do to develop a better theoretical understanding of this family of models.

How exactly will your research impact artificial intelligence?
There is already so much in this field, and things move quickly. What I like about this research subject is that we don't have clear, well-defined problems we want to solve as in many other mathematical fields.

Our goal is to try to understand it. I want to find concepts and mathematical objects that describe how neural networks work, and the NTK has already proven to be a very useful concept. But the first and the most important task is identifying these important objects and finding the right questions to ask, which, as I said, we still don't have.

At the same time, the theory is still behind the practice because so many other people are working on it, as it's a very popular field. Also, the fact that the practice is moving so fast makes it difficult sometimes to follow. However, in the past few years, the theory has progressed a lot, and some theoretical results are already starting to be used. The recent large language models are so expensive to train, that the traditional approach of testing an array of possible hyper-parameters is becoming less viable, and theoretical approaches are getting used. And I think that we will see more and more of that in the future.

You transitioned from PhD to assistant professor. What advice would you give to a PhD student pursuing an academic career?
I was fortunate. Of course, I worked a lot, but sometimes you have just one paper with a significant impact, and it isn't easy to predict this impact in advance. Generally, I was considering several different problems, but you cannot be sure which you will be able to solve.

> Sometimes, coming from outside can end up in unexpected results.

What's nice with maths, and especially in machine learning, is that you always know that you can find another place to go if it doesn't work out in academia. So I would advise new PhD students to not get stuck on a single career path and stay open to other opportunities. The PhD allows you to work on interesting projects quite freely, and with the right mix of luck and talent you can get some important results and a lot of citations, but if you don't, you will still have learned things that are valued outside of academia.

The beauty of research is that it's always a gamble. You can work for a long time on a problem and not get anything; other times, you get very nice results quickly. It isn't easy to know in advance.

Were you surprised by your results?
Yes, because at first, I didn't expect this simplification. So, we introduced this NTK object, which allows you to approximate these neural networks, which are nonlinear models, by a tangent linear model at any point. And so, my first intuition was that since we understand linear models well but not nonlinear ones, we should think of nonlinear models as linear models that evolve during training. It's some form of meta-learning where you are learning the parameters of the model and the model itself simultaneously. That was my first goal. The first proof I was working on when I came to Clément Hongler was that at initialization, we could describe this approximated linear model exactly in the infinite neuron limit, so we knew at least what would be the most similar linear model at initialization. But I was always expecting to see it evolving in time because I expected to see some kind of feature learning. We carried out some experiments and found that, in practice, the more neurons we had, the less the NTK moved, which meant that our description of the model at initialization could be extended to the whole training time in the infinite neuron limit. And this meant that everything could be simplified, and that's how we ended up with our result. I didn't expect such a simple result at the end, the simplicity of the final dynamics.

One advantage I had was that I was working with Clément and Franck, who were not necessarily working in the field of deep learning. So we had an outside perspective and took a very different approach. But it was also a gamble because if things didn't work out so well, it would have been more difficult to get visibility for our results. But sometimes, if your supervisor is well-known in the field, he will probably have the same kind of ideas as everyone else. Sometimes coming from outside can end up in unexpected results.

Conversation with Arthur Jacot
Formerly: EPFL, C. Hongler's group

Interviewed by Mayra Lirot
NCCR SwissMAP

Wei QIAN

(City University of Hong Kong)

Wei Qian received her Master's degree from Université Marie-Curie in Paris in 2013. She joined at the start of the NCCR SwissMAP program in 2014 in Wendelin Werner's Group at ETH Zurich. She was awarded the 2017 SwissMAP Innovator Prize for her work in two-dimensional random geometry related to the Gaussian Free Field, particularly on decompositions of two-dimensional Brownian loop-soup clusters. She obtained her PhD in 2017.

After three years as a Junior Research Fellow at Churchill College and Research Associate at the University of Cambridge, Wei started as a Chargée de Recherche at CNRS and Université Paris-Saclay in 2020. She joined City University of Hong Kong in 2022, and is currently on leave from CNRS.

Her research is focused on probability theory and mathematical physics. She mainly works on random two-dimensional geometry.

Can you briefly explain your work?
I work mainly in the domain of probability theory and mathematical physics. More concretely, I mostly study random objects in dimension two. Many different discrete models in statistical physics converge in the scaling limit to several common objects in the continuum. This phenomenon is called "universality". The respective objects in the continuum exhibit nice symmetries under conformal transformations, and are intimately connected to conformal field theory.

Why did you choose this domain of research?
I decided to enter this domain of research during my Master's degree in Paris, where I attended a class by Wendelin Werner. I remember he gave an overview of subjects in this field of probability, and explained everything in a really original and insightful way. I was totally fascinated.

More broadly speaking, this is a relatively recent domain which has been growing in the last decades. This makes it an exciting domain where people keep discovering new and important results.

At first glance, the objects that I work with are rather geometric, and I enjoy the fact that we can visualise the objects. However, when you dig further, you can see that this domain offers a rich interaction between many aspects of mathematics such as geometry, analysis, probability, combinatorics and algebra. Finally, the fact that it is connected to physics means it's not just "abstract maths theory". For example, we study phase transitions, and they occur in many systems in real life. More abstractly, random geometry is connected to quantum field theory and will therefore eventually help us understand the universe.

What is your favourite part about being a mathematician or maths in general?
I appreciate the fact that you have a lot of freedom in organising your time and deciding how you work. In addition, it is a very creative job, and you do not fall into routine work. This is an attractive career for those who, like myself, enjoy intellectual challenges. You keep learning and discovering new things and feel like you are contributing to human knowledge.

Do you have any hobbies?
I really like literature, cinema, music and travel. Even though maths demands me a lot of time, I still believe that my other interests are equally important aspects of my life. Mathematics is a very competitive field, and many good mathematicians actually devote their entire time to research. Finding a balance between work and life is one of the biggest challenges I have.

In general, I am interested in many things outside of mathematics. There are so many possible points of view on the world around us. Although mathematics is a very powerful subject, it is also rather narrow, and cannot be used to explain everything about the world.

Who inspires you in mathematics?
The first person who comes to mind is my PhD advisor Wendelin Werner as it is how I started doing research. He has such a free and original way of doing research, which stimulates my imagination. Doing research with him is a great pleasure.

I also want to mention a mathematician in the early 20th century, Bertrand Russell, whom I find inspiring and unique. He worked on logics for the first half of his life. In the second half of his life, he became a philosopher. I am deeply influenced by several of his books on philosophy. He pursued his intellectual interests freely. Nowadays, it is very rare for someone to be both a mathematician and a philosopher.

And who do you admire outside mathematics?
I like cinema, and admire many film-makers. For example, I would like to mention Jia Zhangke, who is an internationally well-known Chinese director. I am particularly impressed by his first film "Xiao Wu". He paints a realistic and compassionate picture about the lives of ordinary people in China from small cities or rural areas. His films document the rapid changes in Chinese society. I grew up in a similar environment, in a small city, and my father comes from the countryside, so I feel a deep empathy towards the characters in his films.

And what advice would you give a student who wants to pursue an academic path?
There are different levels of advice. There is practical advice, such as achieving a better CV and finding jobs. These would be better handled by the advisor.

I would say that the most important thing is to know why you chose this path. Make sure that it's something you like to do, even though it can be difficult. The most essential quality of a good researcher, I would say, is to think independently and critically.

Did you consider the industry at any point?
I did not want to work in companies, because it seemed difficult for me to be convinced about the activities and values of many companies. In a company, it is difficult to have the kind of autonomy that you have in academia.

Conversation with Wei Qian
Formerly: ETHZ, W. Werner's group

Interviewed by Mayra Lirot
NCCR SwissMAP

Upcoming Events

Scientific Program 2024

SRS
SwissMAP Research Station in Les Diablerets

Winter school in mathematical physics
January 7-12
A. Alekseev (UNIGE), A. Cattaneo (UZH), G. Felder (ETH Zurich), M. Podkopaeva (IHES), T. Strobl (U. Lyon 1), A. Szenes (UNIGE).

Quantum topology biennial: focus on representation theory
January 14-19
A. Beliakova (UZH), O. Kivinen (EPF Lausanne), A. Lachowska (EPF Lausanne), Y. Qi (U. Virginia), L-H. Robert (U. Clermont-Auvergne).

Conformal field theory 3 ways: integrable, probabilistic, and supersymmetric
January 21-26
F. Del Monte (U. Montreal), H. Desiraju (U. Sydney), A. Grassi (CERN & UNIGE), V. Vargas (UNIGE).

Workshop on the enumerative geometry of the Hilbert scheme of points
January 28 - February 2
G. Bérczi (U. Aarhus), A. Szenes (UNIGE).

Phase mixing, kinetic theory and fluid mechanics
February 4-9
M. Coti Zelati (Imperial College London), M. Iacobelli (ETH Zurich).

Quantum metrology in many-body open systems
February 11-16
N. Brunner (UNIGE), G. Haack (UNIGE), P. Lipka-Bartosik (UNIGE), M. Mehboudi (UNIGE), M. Perarnau-Llobet (UNIGE), P. Sekatski (UNIGE).

Workshop in mathematical physics 2024
February 18-23
A. Logunov (UNIGE), S. Smirnov (UNIGE).

Quantum information
February 25 - March 1
M. Christandl (U. Copenhagen), R. Renner (ETH Zurich).

Advanced lectures in physics in Switzerland
May 12-17
R. Baumgartner (UNIGE), A. Florio (Brookhaven NL), V. Pellizzani (UNIBE), D. Youmans (U. Heidelberg).

Gravitational physics and its mathematical analysis
June 2-7
P. Hintz (ETH Zurich), C. Kehle (ETH Zurich), G. Moschidis (EPF Lausanne).

Birational geometry and dynamics
June 30 - July 5
F. Bernasconi (EPF Lausanne), J. Blanc (UNIBAS), A. Bot (UNIBAS), Z. Patakfalvi (EPF Lausanne), J. Schneider (EPF Lausanne), E. Yasinsky (Ecole Polytechnique).

Quantum key distribution summer school
August 18-23
R. Renner (ETH Zurich), M. Sandfuchs (ETH Zurich), R. Wolf (ETH Zurich).

Topologically recursive behaviors
August 25-30
D. Lewanski (U. Trieste), N. Orantin (UNIGE).

Matrix x IMAGINARY
August 31 - September 4
S. Fiorelli (UNIGE), C. Lawrence (MoMath), A.D. Matt (IMAGINARY), E. Raphael (UNIGE).

Quantization in representation theory, derived algebraic geometry, and gauge theory
September 15-20
A. Appel (U. Parma), L. Bossinger (UNAM México), G. Felder (ETH Zurich), M. Porta (U. Strasbourg), F. Sala (U. Pisa), O. Schiffmann (U. Paris-Saclay).

12th International conference on the Exact Renormalization Group 2024 (ERG 2024)
September 22-27
L. Classen (MPI Stuttgart), N. Defenu (ETH Zurich), F. Rennecke (JLU Giessen), L. Zambelli (INFN-Bologna).

In 2024

Conference En mémoire d'André Haefliger
Our colleague and friend André Haefliger passed away on 7 March 2023, shortly before his 94th birthday. The conference includes talks by Martin Bridson (Oxford), Marc Burger (ETH Zurich), David Carchedi (George Mason), Yakov Eliashberg (Stanford), Rui Fernandes (Urbana-Champaign), Étienne Ghys (ENS Lyon), Pierre de la Harpe (Geneva), André Henriques (Oxford), François Laudenbach (Nantes), Marc Troyanov (EPFL).

Past Events

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

2023

- Effective theories in classical and quantum particle systems (June 18 – 23)
- Finite dimensional integrability in mathematical physics (June 11 – 16)
- Analytic techniques in Dynamics and Geometry (May 28 – June 2)
- Geometric and analytic aspects of the Quantum Hall effect (May 7 – 12)
- Integrability in Condensed Matter Physics and Quantum Field Theory (Feb 3 – 12)

2022

Winter School in Mathematical Physics 2022
(Jan 9 – 14)
Mini courses by Giovanni Felder (ETH Zurich), Matthias Gaberdiel (ETH Zurich) and Marco Gualtieri (University of Toronto).

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

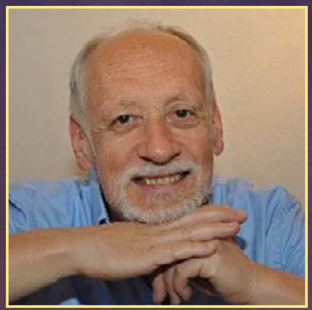
Awards & Grants

Alberto Cattaneo

COST project

Alberto Cattaneo (UZH) is part of the recently approved COST project: *Cartan geometry, Lie, Integrable Systems, quantum group Theories for Applications.* The COST programme (European Cooperation in Science and Technology) brings together European researchers. COST activities are carried out in the form of networks, called COST Actions.

Nicolas Gisin



Paul Ehrenfest Best Paper Award 2022

The winning paper is: *Quantum theory based on real numbers can be experimentally falsified*, by Marc-Olivier Renou, David Trillo, Mirjam Weilenmann, Thinh P. Le, Armin Tavakoli, Nicolas Gisin, Antonio Acín and Miguel Navascués, Nature 600, 625 (2021).

Peter Hintz

2022 Golden Owl

Congratulations to our member Peter Hintz (ETH Zurich) who was awarded the 2022 Golden Owl by the VSETH, ETH Zurich's students association, who are also the initiators of the award. The Golden Owl honours lecturers who have provided exceptional teaching and motivates them to continue with their excellent teaching.

Chiara Saffirio

ERC Starting Grant

Congratulations to our member Chiara Saffirio (UniBas) for receiving an ERC Starting Grant for the project: *Advances in effective evolution equations for classical and quantum systems (AEQUA).*

Julian Sonner

SNSF Project funding

Congratulations to our member Julian Sonner (UNIGE) for receiving SNSF Project funding for the project: "*Order from chaos: taming quantum gravity with quantum chaos*" from 01.06.2023 – 31.05.2027. With its project funding scheme, the SNSF enables researchers to independently conduct research projects with topics and goals of their own choice.

Maryna Viazovska

BBC 100 Women 2022

Our member Maryna Viazovska (EPFL) is in the list of BBC 100 Women 2022. BBC names 100 influential and inspiring women around the world every year. The BBC creates documentaries, features and interviews about their lives - stories that put women at the centre.

Vincent Vargas

SNSF Project Funding

The project submitted by our member Vincent Vargas (UNIGE) "*2d constructive field theory with exponential interactions*" was recently selected as part of the SNSF Project Funding Scheme and will run from 01.10.2022 – 30.09.2026. The project partners are Colin Guillarmou (Paris), Antti Kupiainen (Helsinki) and Rémi Rhodes (Marseille).

Hugo Duminil-Copin, Aleksandr Logunov and Corinna Ulcigrai

SNSF Consolidator Grants

Hugo Duminil-Copin (UNIGE) for the project entitled "*Emerging symmetries in critical systems of statistical physics*". Aleksandr Logunov (UNIGE) for the project "*Nodal geometry and quantitative analysis of eigenfunctions*". And Corinna Ulcigrai (UZH) for the project entitled "*New Frontiers of Renormalization*". This financial support was set up by the SNSF in 2022 in order to compensate for European programs that are no longer accessible to researchers from Swiss universities.

SwissMAP Innovator Prize

Dmitrii Krachun, Adrián Sánchez Garrido and Olga Trapeznikova

2023 Prize Winners

Congratulations to our members Dmitrii Krachun (UNIGE, S. Smirnov's Group), Adrián Sánchez Garrido (UNIGE, J. Sonner's Group) and Olga Trapeznikova (UNIGE, A. Szenes' Group) who have been awarded the SwissMAP Innovator Prize 2023!

The SwissMAP Innovator Prize is awarded once a year to PhD students or Postdocs for important scientific achievements in the NCCR SwissMAP research areas.

New Members

Martin Hairer
EPFL

We welcome our new professor Martin Hairer (2014 Fields Medal). He joined the *Statistical Mechanics and Random Structures* & *Differential equations of Mathematical Physics* SwissMAP Phase III Directions.

Martin's main research interest is the study of stochastic partial differential equations (SPDEs), with a focus on singular SPDEs. Other research interests include nonequilibrium statistical mechanics, quantum field theory, stochastic differential equations, stochastic processes with memory, and the general theory of Markov processes.

Xue-Mei Li
EPFL

We welcome our new professor Xue-Mei Li. She joined the *Statistical Mechanics and Random Structures* & *Differential equations of Mathematical Physics* SwissMAP Phase III Directions.

Xue-Mei is interested in random evolutions, namely stochastic processes, stochastic equations, stochastic dynamics, and geometric stochastic analysis, analysis of path spaces.

Georgios Moschidis
EPFL

We welcome our new SwissMAP member Prof. Georgios Moschidis. He joined the *From Field Theory to Geometry and Topology* direction.

His research interests cover a broad collection of topics in mathematical general relativity, including the threshold of well-posedness for the Einstein field equations, problems associated with the long-time dynamics of solutions (where phenomena such as turbulence and superradiance emerge) and the spacetime geometry in the regime of trapped surface formation.

Klaus Widmayer
UZH Zurich

We welcome our new SwissMAP member Prof. Klaus Widmayer. He joined the *Differential equations of Mathematical Physics* direction.

His research interests are in the analysis of partial differential equations. More specifically, he works on questions of stability and asymptotic behavior in evolution equations of fluid dynamics and kinetic theory.

Promotions

Mikaela Iacobelli
Professor

Congratulations to Mikaela Iacobelli (ETH Zurich) who was appointed professor earlier this month by the ETH Board. Mikaela conducts research in the area of mathematical physics with the aim of using mathematical methods to solve physical problems.

João Penedones
Associate Professor

The ETH Board has promoted João Penedones to Associate Professor at the EPFL School of Basic Sciences (SB). João works in the field of quantum field theory and quantum gravity. He currently runs the Fields and Strings Laboratory while also taking a leading role in the new Bernoulli Centre.

Alba Grassi
AcademiaNet

We are pleased to inform you that the SNSF has nominated Alba Grassi (CERN & UNIGE) to join AcademiaNet – the expert database for outstanding female academics.

The database at *www.academia-net.org* lists more than 3'500 top-class female researchers of all disciplines for their outstanding qualifications and achievements.

Phase III

SwissMAP Steering Committee

We welcome the following new members to the Phase III SwissMAP Steering Committee: Kyriakos Papadodimas (CERN) & Julian Sonner (UNIGE). The SwissMAP co-Director will be Matthias Gaberdiel (ETH Zurich), who was previously Deputy Director, and Renato Renner (ETH Zurich) will take over as SwissMAP Deputy Director.

Moreover, we would like to express our sincere gratitude to our former Steering Committee members: Giovanni Felder (ETH Zurich), Wolfgang Lerche (CERN) and Marcos Mariño (UNIGE) for their continued commitment and valuable contributions to the program's mission.

Puzzle Corner

1. Equal Numbers

An integer is written down in each unit square of a board 2×3.

In one step, Bob:

- selects a set of squares;
- for each selected square, he computes the average of the numbers in the neighboring squares (sharing a side);
- replaces the entry in each selected square by the corresponding average.

Can Bob always make all the numbers equal?

3	12	7
4	-1	0

2. The Number Twister

The last digit of a three-digit number is moved to the beginning (e.g. 123 –> 312). The resulting number is added to the original number. The sum is 1000.

What is the original number? Find all the possible variations.

3. A Look into the Future

The number of the year 2016 is dividable by 9, 8, 7, 6, 4, 3, 2 and 1. Would the next year with exactly the same properties, also happen to be dividable by 5?

4. Six Natural Numbers

Find six different natural numbers for which the product of any two numbers is not dividable by the sum of all numbers and the product of any three numbers is dividable by the sum of all numbers.

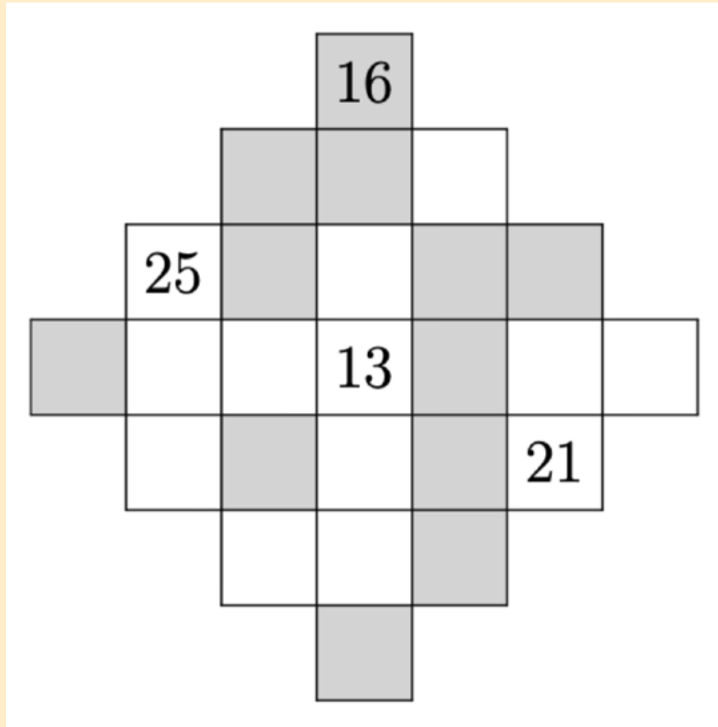
5. The Cross Grid

Fill in the grid with the numbers 1 to 25, using each number exactly once. The following applies:

1. each shaded square contains an even number, and each non-shaded square contains an odd number.

2. for each pair of squares that have a common side, if x and y are the two numbers in these squares, then either x ≥ 2y or y ≥ 2x.

Four numbers have already been filled in:



Answers

1. Equal Numbers

No, he cannot always make all the numbers equal.

At all times, the entries are rationals with denominators involving only powers of 2 and 3, so the entries can be reduced modulo 5. But in the following board

-1	3	-1
0	1	0

observe that

- Each entry is the average of its neighbors modulo 5;
- So, the entries never change modulo 5, no matter what steps Bob performs;
- The entries are not all equal modulo 5;
- Therefore, the entries as Bob performs the operation will never have the same reduction modulo 5;
- Therefore, the entries can never become equal as rationals.

This is a version of APMO'2019, P4 and was discussed in the advanced class of the ETH Math Youth Academy.

2. The Number Twister

The number you are looking for is 455. There is only one solution.

3. A Look into the Future

The next year is 2520.

The numbers that are dividable by 1, 2, 3, 4, 6, 7, 8, 9 are also dividable by their smallest common multiple 504. The next year would then be 2016 + 504 = 2520. It is also divisible by 5.

4. Six Natural Numbers

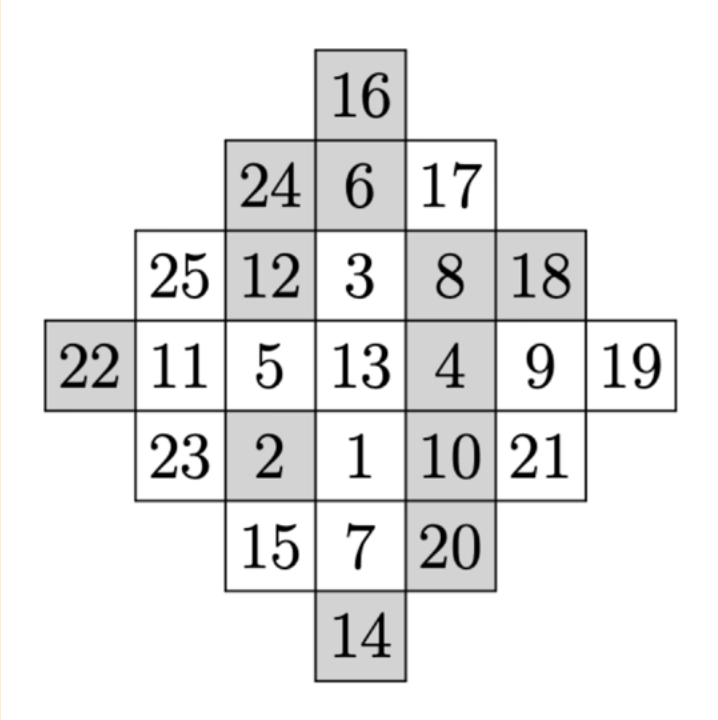
For example 5, 10, 15, 20, 30, 45.

Let p be a relatively large prime number. We represent p^2 as the sum a1 + a2 + … + a6, where none of the summands are dividable by p. For example: p=5 and p^2 = 25 = 1 + 2 + 3 + 4 + 6 + 9.

The numbers pa1, pa2, … , pa6 fulfil the prerequisites: The product of any two p^2·ai·aj is not dividable by the sum of ALL numbers S = pa1 + pa2 + … + pa6 = p^3, but the product of any three numbers IS dividable by p^3.

For p = 5 and the breakdown from above, you get the numbers 5, 10, 15, 20, 30, 45.

5. The Cross Grid



Puzzle contributors:

No 1: Kaloyan Slavov (ETH Zurich) | ETH Math Youth Academy | https://people.math.ethz.ch/~kslavov/

No 2, 3, 4, 5: Dmitrij Nikolenkov (ETH Zurich) | TagesAnzeiger's - Hier trainieren Sie Ihr Hirn | https://www.tagesanzeiger.ch/ (Folge 299, 300 des Zahlendrehers)

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Cover & center photo: Julien Gaspoz Photographe, *Les Diablerets*

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Swiss National Science Foundation

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