SwissMAP
The Mathematics of Physics
National Centre of Competence in Research

SwissMAP Perspectives

Issue 5 | 2020

Special Edition:
Outreach & Education

Contents

Presenting the

SwissMAP Research Station (SRS)

SwissMAP is proud to announce that the SwissMAP Research Station (SRS), a joint venture of the University of Geneva and ETH Zurich, will open in January 2021 and will be based in Les Diablerets, Switzerland. The SRS will be dedicated to the organization of events in Mathematical Physics (conferences, workshops, thematic meetings) and also outreach. The (SRS) website (swissmaprs.ch) was launched early Spring this year.

Currently available online:

- SwissMAP Research Station 2021 programme;
- Call for 2022 proposals, submission deadline: 30th September 2020.

SwissMAP Research Station Goals:

- To ensure the sustainability of NCCR SwissMAP activities in Mathematics and Physics;
- Give international visibility to these activities and to increase their scope by organising international conferences on topical problems in Mathematics and Physics;
- To promote collaborations between different areas of Mathematics and Physics and between different universities in Switzerland;
- To develop undergraduate and graduate studies in Mathematics and Physics, thus ensuring an internationally competitive succession;
- To support equal opportunities and gender balance in the events organised by the Research Station.

SRS
SwissMAP Research
Station in Les Diablerets

a conversation with

Alessandro Sfondrini

After over four years at ETH Zurich, Alessandro Sfondrini (Gaberdiel Group) has taken up a position as "Rita Levi Montalcini Fellow" at the Department of Physics and Astronomy of the University of Padova.

This position, equivalent to Assistant Professor with tenure-track in the Swiss system, allows him to carry out independent research on the interplay between string theory, conformal field theory, and integrable systems.

Until summer 2020 he will still be at the ETH Zurich as a long-term visitor to manage a related SNF "Spark" grant which he recently obtained.

Following the success of his two videos on string theory, we conducted an interview with Alessandro to talk about how these videos came to be.

The first video, "*Why Black Holes Could Delete The Universe – The Information Paradox*", has reached over 18 million views. The second video, "*String Theory Explained – What is The True Nature of Reality?*" has reached over 13 million views.

- What gave you the idea to create these videos?

There are a lot of excellent videos on YouTube about science, such as physics and mathematics. But not many of them are done in collaboration with scientists. And not many of them are about string theory, or are on the frontier of theoretical physics and mathematical physics. So I always wanted to bring a little bit of what I know to this sort of medium, in order to reach more people, and specifically students. This is something that I already had in mind, even before coming to Switzerland. Then after coming here, I found that the Swiss government, through the Swiss National Science Foundation, and SwissMAP could be great partners in supporting what is actually a very complicated endeavour: to create these videos, find the right partners, find the right funds, and eventually publish the completed videos.

- To make such a video, you need a scientific background, but you also need to develop skills as a filmmaker. So how do you navigate these various roles to create the final product?

I could not have done it on my own. I had great help from the very talented people of the YouTube channel Kurzgesagt, which is German for "in a nutshell". They have a lot of experience in making videos on biology, engineering, energy, and so on. And in this case, it was really a matter of putting together my expertise and knowledge, with their experience on engaging people and having the best form of visual communication, the best choice of words, the best timing of our spoken sentences and so on. So it was really crucial to work together with them and there was a lot of learning opportunities on both sides.

- What was the role of Kurzgesagt?

Their role was to help me put my idea, which was rather abstract, into the correct format. They helped choose the right length, the right topic and the right way of phrasing the questions and sentences. So in practice, that meant that I told them about physics. I gave them material to read and we had numerous discussions. Then we started writing a script. They prepared a draft and I gave them my comments. And we went back and forth using this process, resulting in around 15 drafts for each video. Eventually, when we were both happy, they started preparing the art and the storyboard. Even then, it was very important that we were both engaged, because there are different ways to illustrate a physical concept and it's very easy to make very small mistakes that can be misleading, but only a scientist would recognise it as something misleading.

- What is the timescale for producing a video like this, from conception to completion?

It takes several months. First there is the research period. Of course as a scientist, I'm already familiar with the topic of the videos, but the people working at Kurzgesagt, are not. So they need time to read and understand the material in their own way. And also, I need time to rethink the material. I need to find the best way to present my knowledge, which is mostly technical, in a way that can be absorbed by somebody who isn't a specialist. All this takes about 1-2 months. After that, the scriptwriting starts, and that takes a few weeks. There is the process of back and forth between drafts. Afterwards, the actual illustration and animation starts, and that also takes a few weeks. This is actually a job for several people, because computer animated videos require of course a lot of expertise and a lot of hours. Then to top it all off, there is the recording of the voice actor, the creation of the music and other final touches. So all in all, you're looking at maybe 3-4 months from the moment when you really start working on it.

- Did you consult with teachers or students?

Yes, that was a very important part of the process. At several stages of the project, I got in touch with high school students in Zurich and their teachers. The idea was first to understand what could be interesting for them. And then, as the writing of the script progressed, to get some feedback on the text. Because for somebody who was in high school perhaps 10-20 years ago, it is very difficult to remember exactly what a high school student knows. And some metaphors that are common language for people from a certain generation are no longer relevant for people who are younger. You have to adapt your language in certain subtle ways. So this sort of feedback was crucial and even to this day, we try to be as engaged as possible with students and teachers for all parts of the project, such as finding the best way to distribute these videos to the schools.

- The videos have had great success. Did you expect this?

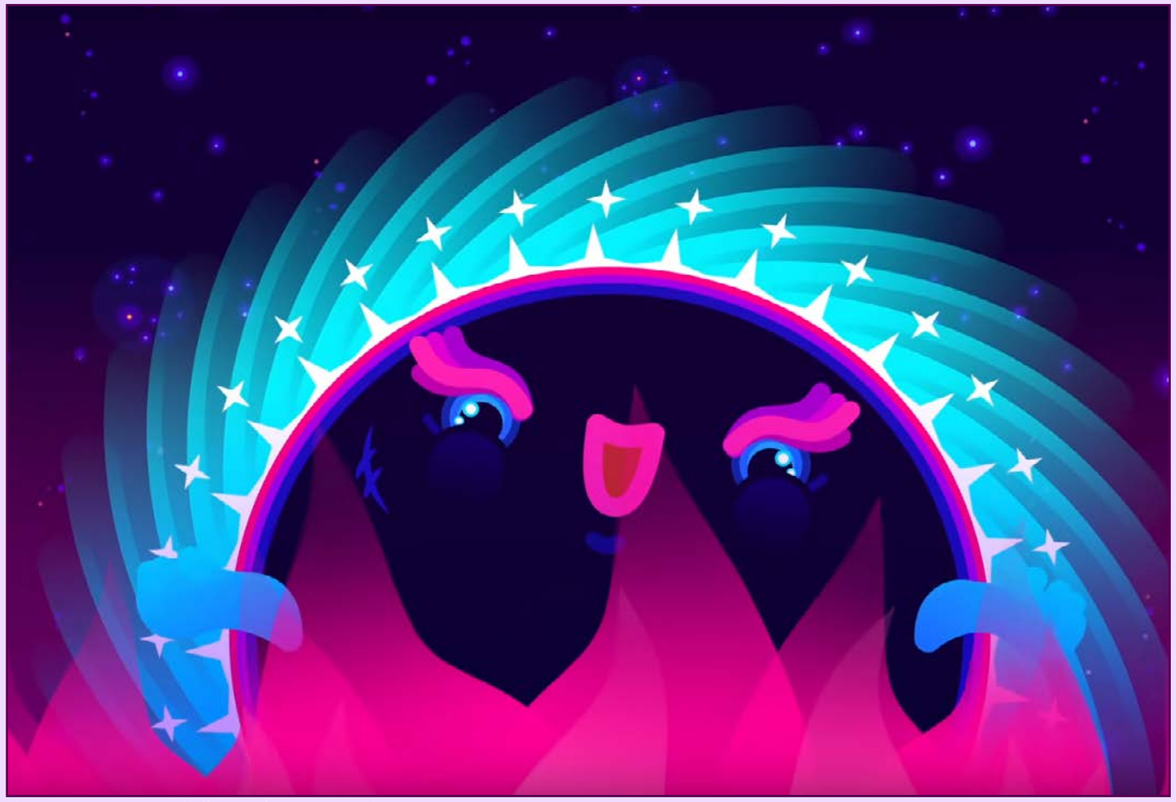
It was a bit of a surprise. I knew that by working with Kurzgesagt, who are a very talented group of people and are very well known on YouTube, I would have some amount of success. In my original proposal I wrote that I would expect at least two million people to view the videos. And now, although we are only at the beginning of the project, already millions of people have seen the videos. So this is testimony to the quality of the videos, and the need for good outreach in theoretical physics and mathematics. There is still of course an important step to make, which is to go to the schools and make sure that not only the students see the videos, but they also get a chance to talk about them. With scientists, with their teachers and people who can tell them more about what doing science is actually like.

- What channels where used to promote the videos?

Well the main channel was the Kurzgesagt YouTube channel and their social media. This is of course for the English version of the videos. Now we also have French, Italian and German versions as well. They have been promoted through the Swiss- MAP YouTube channel and through the social media of SwissMAP, ETH Zurich and of course Kurzgesagt. This is a direct way to make the videos immediately available on the internet. Apart from that, we will also contact the schools to make the teachers aware of the existence of these videos. This is very useful so that people consider this project as not only something that exists on the internet, but a real world activity that is tangible and that they can work with on a person to person basis.

There are a lot of excellent videos on YouTube about science, such as physics and mathematics. But not many of them are done in collaboration with scientists.

Another important resource is our website: http://physdocu.ethz.ch/ This collects all the material that we have. Not only the videos in several languages, but also materials for the teachers, and for the students. There are additional explanations and very nice posters that you can put up in your high school or university, to popularise this event or events that you can create related to this project. And it's also the best way to contact us.



Kurzgesagt – In a Nutshell. youtube.com/user/Kurzgesagt

There is a form for teachers or other interested people to get in touch with us.

- Are the videos part of a larger activity?

Yes, indeed. The videos are just the tip of the iceberg. The important thing here for us, and for the Swiss National Science Foundation, is really to have a dialog between scientists and the public, in this case high school students. So just showing them a video would not be enough. What is important here is to give students a chance to think about what is in the video and to start a conversation with scientists. This could be a PhD student, a postdoc, or a professor. People who have their own view of science; their own personal experience. And they can not only talk about the topic of the videos, but about the whole experience of being a scientist.

- What is your long term vision for how the videos should be used?

We want to get these videos out to as many people as possible. The videos will always be there. And the materials we produce and the explanations that have to do with the videos will always be there. We would like them to have a life of their own. For instance, high school teachers can continue to work with these videos, show them in their classes, and invite researchers from universities to their schools.

- Do you have any plans for future videos?

Not right now. The important thing is to get the word out on the videos that are already there. Of course, it is very tempting, given the success of these videos, to consider doing more. But this is something that is very expensive. Not only in terms of money, but also in terms of commitment. Because if you want to do something like this, you should do it well, and that takes time and energy. So before thinking about that, I would like to see this activity to the end. And maybe convince some colleague that this is something that could be interesting for them. For instance in the realm of mathematics, which we don't really touch upon, but which suffers to some extent, from the same problems that theoretical physics suffer from. Some students find it un-engaging. They find it too difficult, without ever being exposed to real world mathematics. And I'm sure that there are numerous problems in mathematics that would be perfect for these types of videos.

What is important here is to give students a chance to think about what is in the video and start a conversation with scientists. They can not only talk about the topic of the videos, but about the whole experience of being a scientist.

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

What I would say to other scientists who are thinking about doing outreach, is not to be afraid to give it a try. At least start by dipping your feet in the water with some small activity. And then maybe look at the more complicated and more rewarding activities that you can do thanks to the funding instruments of the Swiss National Science Foundation or in collaboration with entities like SwissMAP or your own university. You should also be aware, that there is a lot of attention in Switzerland towards outreach, from the government, funding agencies and universities. And you will find great support. You will find dedicated staff in the universities that can explain to you how to reach out to schools or people you don't normally talk to. And there are a lot of funding instruments to discover that can also support you. Not only financially, but also in better developing the concept of outreach. So my advice to everybody would be to give it a try, even if you have just a little bit of time.

The videos will always be there. And the materials we produce and the explanations that have to do with the videos will always be there. We would like them to have a life of their own.

You can watch both videos here:
http://physdo cu.ethz.ch/

Alessandro Sfondrini during the interview at the SwissMAP General Meeting 2018.

Conversation with
Alessandro Sfondrini
September 2018, Grindelwald

Interviewed by Maria Kondratieva
On behalf of the NCCR SwissMAP

Presenting:
MATHSCOPE

The Mathscope, part of the University of Geneva's Scienscope, has been hosting numerous classes since 2015 and regularly participates in various events. The Mathscope's vocation is to propose fun activities in mathematics, in order to make students discover this discipline in a different way than the one usually adopted by schools. The activities allow the participants to explore different mathematical subjects, from geometry to probability, algebra and topology. Each activity lasts one hour and focuses on the manipulation of objects, which then allows the students to develop their reasoning about a mathematical problem. The Mathscope welcomes school students of all ages. Usually, teachers book a Mathscope activity because they want to show the students another perspective of mathematics. Some groups are also made up of adults who want to enjoy science.

Credit: Joana Mailler

The Mathscope, financed by SwissMAP, hires instructors who lead and develop the activities as well as the class materials.
In 2019 alone, the Mathscope workshops welcomed around 6'000 visitors. In addition, there were also visitors at the various events in which the Mathscope participated. These are mainly based on three axes: activities within schools, participation in major public events and Scienscope's own initiatives. Particular attention is also paid to raising public awareness of mathematics, especially amongst young girls.
Like every year, the Mathscope took part in the a Scienscope initiative *(R)amène ta Science*. This project invites schoolchildren to take ownership of science through kits that are presented to them and which they must then present in turn to their classmates and teachers at their school. Three schools benefited from this programme for the year 2018-2019.
In March 2019, the Mathscope was invited by the *Bibliothèque de Genève* to propose mathematical activities for the general public during a unique event: the presentation to the public of Luca Pacioli's manuscript, *De Divina Proportione*, in which hand drawings supposedly by Leonardo da Vinci, can be found.
The Mathscope participated with the Scienscope in the *Nuit des Musées* 2019 in Geneva, as part of the activities proposed by the Museum of History of Science around the theme « Top Secret ».
The issue of the accessibility of science for women is of great concern to Mathscope, who participates in two flagship events: *Elargis tes horizons* and the International Day of Women and Girls in Science. Every two years, *Elargis tes horizons* offers girls aged 11 to 14 years old the opportunity to discover science through workshops and booths throughout the day. For the International Day of Women and Girls in Science, the Mathscope, as well as other Scienscope platforms, the CERN and EPFL, send women researchers to local schools to present their work.
The Mathscope also took part in *Futur en tous genres*, a programme aimed at 12-13 years old students to raise awareness among young people about gender stereotypes related to jobs; Mathscope offered two workshops.

Credit: Joana Mailler

Finally, two major events mobilized the Mathscope and the Scienscope. Firstly, the project *« Et si j'étais scientifique… »*. The Scienscope has set up a program for 10-11 years old students. At first, students were invited to the University to attend an interactive play written especially for the occasion by Fathi Ben Aribi, SwissMAP post-doctoral fellow. A few days after the play, students returned to the University, with their class, to visit one of the Scienscope laboratories, including the Mathscope, and complete an activity related to the play.
The other event of great importance was the exhibition *"Leonardo in Perspective"*.

Mathscope's vocation is to propose fun activities in mathematics, in order to make students discover this discipline in a different way than the one usually adopted by schools.

Credit: Joana Mailler

Mathscope UNIGE

Teacher's message after visiting Mathscope:
"I would like to sincerely thank you on behalf of our school for the remarkable quality of the visit to Mathscope! Our students and accompanying teachers were all delighted. These moments are precious for our students."

Authors: Joana Mailler and Shaula Fiorelli
UniGE

Leonardo en perspective

Exhibition

To mark the 500th anniversary of Leonardo da Vinci's death, Swiss-MAP members Shaula Fiorelli and Joana Mailler, respectively co-director and scientific assistant of the Mathscope, set up an exhibition around this universally known genius. This project was set up under the aegis of the Scienscope and the University of Geneva, and involved several partners: the Earth Sciences Department's Terrascope as well as the Astronomy Department of the Faculty of Sciences, the Departments of Musicology, Italian and History and Philosophy of Science of the Faculty of Arts, the NCCR ChemBio, the Animuse and *Mondes Imaginaires* associations, the Martin Bodmer Foundation and the Bibliothèque de Genève (BGE). The aim of the exhibition was to celebrate Leonardo's genius by presenting some of his lesser-known research and contributions in fields such as music, mathematics, astronomy, earth sciences and biochemistry.

The exhibition was financially supported by the SNSF, through an Agora project, but also by the Wright Foundation and the University of Geneva.

Polish musician and instrument maker, Sławomir Zubrzycki. Photo by N. Wenger

The idea for this exhibition came after an event organised by the Bibliothèque de Genève several months earlier: an invaluable manuscript preserved at the BGE was presented to the public in 2019. It is a manuscript by Luca Pacioli, a Renaissance mathematician, which presents, among other things, magnificent drawings of polyhedra. These drawings are said to have been conceptualized and possibly executed by Leonardo da Vinci, who was a friend of Luca Pacioli. The event at the BGE was programmed over two days and welcomed over than 1000 visitors. In view of the great interest shown, it seemed only logical that the University should, as everywhere else in Europe, participate in the celebrations linked to the 500th anniversary of Leonardo's death.

The exhibition took place in the exhibition hall of the University of Geneva from 18th December 2019 to 20th February 2020 and offered interactive activities for the public (a perspectographer in math, videos on the *viola organista* in musicology, a model to observe the planetshine in astronomy, a device with sand and a projector to understand topographical changes in earth science, etc.). The exhibition, which was very well documented, also presented facsimiles of manuscripts by Leonardo's hand, on loan from the Martin Bodmer Foundation, as well as the facsimile of Luca Pacioli's manuscripts on loan from the Bibliothèque de Genève. A wide programme of visits, workshops and activities was offered to the public with activities especially dedicated to families and classes. The exhibition also hosted a concert with the Polish musician and instrument maker, Sławomir Zubrzycki, who recreated the *viola organista*, an instrument conceptualized by Leonardo da Vinci. Finally, a corner dedicated to outreach displayed the work produced by both young and old for the contest organised by the University's magazine Campus Junior: "Draw your Mona Lisa".

During the almost two months of display, the exhibition benefited from local and national press coverage and welcomed over 4,000 visitors, a record for the University's exhibition hall. The feedback from visitors, teachers and participants has been extremely positive, proving once again that Leonardo continues to fascinate throughout time.

Da Vinci Vernissage. Photo by B. Jreidi

In order to extend the benefit of this exhibition a series of videos presenting different aspects of the exhibition are available online through the SwissMAP YouTube channel.

A wide programme of visits, workshops and activities was offered to the public with activities especially dedicated to families and classes.

Da Vinci Vernissage. Photo by B. Jreidi

Author: Joana Mailler
UniGE

A conversation with
Fiona Seibold

Fiona did her Bachelor and Master in Physics at EPFL and has defended her PhD on the 4th of May at ETH Zurich.

She will move to Imperial College London for 2 years starting in October 2020 with Arkady Tseytlin.

- How did you get into physics?
Well, this started quite early on, when I was maybe 12. At that time, I was very much into Maths, whose beauty I found fascinating. I also enjoyed looking at the stars and often wondered how the universe works. When my parents got their first computer at home, I took this opportunity to browse the World Wide Web in search of new interesting mathematical concepts. At some point I reached a website where there was something about string theory as well. This first encounter with theoretical physics was very inspiring. Then, as I entered EPFL, I had to choose between the maths or physics sections. I don't know exactly what pushed me into one direction or another, but I chose Physics and I'm pretty happy it went this way.

- Can you tell us a bit more about your research topic?
My research touches on several aspects of theoretical physics, namely string theory, integrability, and also the AdS/CFT correspondence.
AdS/CFT is a duality between string theories on Anti-de-Sitter space and conformal field theories living in one dimension less. The typical example is the duality between string theory on $AdS_5 \times S^5$ and N = 4 super-Yang-Mills. One thing that came up in the early 2000s is that these two theories are integrable. There exists a lot of conserved charges that can be used to solve the theories exactly. This is extremely important because it can be used to obtain exact results for strongly coupled quantum field theory, which is usually very hard, and also opens the door to actually proving the duality.
So, motivated by this success, people also looked at what happens when you deform the theory away from these most simple examples: for example, is it possible to deform the $AdS_5 \times S^5$ superstring while preserving integrability? It turns out that this is indeed possible and several integrable deformations have been proposed. I am studying these integrable deformations.

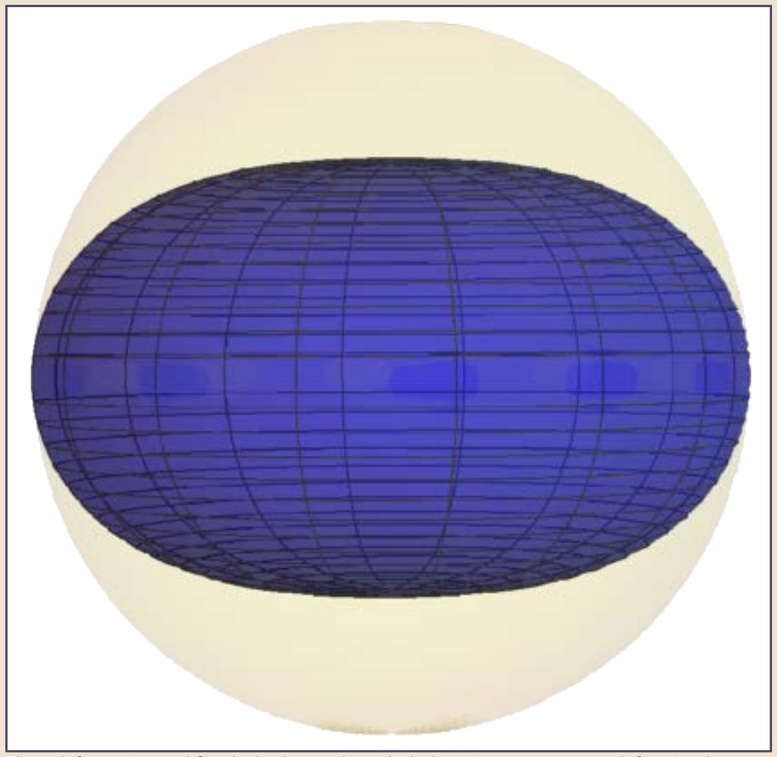
- So are you exploring one in particular?
There are several deformations of the $AdS_5 \times S^5$ superstring that preserve integrability. A special class is given by the so-called Yang-Baxter deformations, and these are the ones that I study. Their effect is to promote the initial symmetry algebra to a quantum group: they are q-deformations.

- What kind of tools are you using?
For analytic calculations I use tools from supergravity and integrability. I also need a lot of concepts from Lie (super)algebras and their q-deformations. Often I have to handle involved expressions, in which case I use computer programs to help me, for instance Mathematica.

- Is your problem something that you think can be solved soon?
There are several open problems in the context of integrable deformations. Perhaps the most challenging one concerns the nature of their CFT duals. We have these q-deformations of the $AdS_5 \times S^5$ superstring, but we still have basically no idea of what their CFT dual is. I think this is a very interesting but also rather complicated question, and for the moment it is hard to see how to tackle it. But I think it will find its epilogue in the next ten years.

- What about the way you are attacking this problem? Is your angle new?
For the moment I focus on the string theory side of the duality, addressing the problem step by step. One important question is if the deformed theories still define string theories. This is important in the context of the AdS/CFT correspondence because on the AdS side we a priori need a string theory.
The q-deformations that I mentioned were believed not to be Weyl invariant, which hindered their interpretation as string theories. During my PhD, together with Ben Hoare, I found a way to construct them so that they are Weyl invariant and thus define consistent string theories. I hope that this new result will help us make progress in finding the CFT dual.

- Are some people attacking the problem from the CFT side?
There is ongoing progress to characterise the CFT duals of integrable deformations. For some simple deformations, the CFT dual is actually known. This is however not the case for q-deformations. People have and still are analysing q-deformations of CFTs, mainly in two dimensions, but the link with the integrable deformations on the string theory side is missing.



The q-deformation modifies the background on which the strings propagate. q-deforming the two-sphere (in brown) results in a squashed geometry (in blue).

My research touches on several aspects of theoretical physics, namely string theory, integrability, and also the AdS/CFT correspondence.

- What are the problems in physics you'd like to see solved?
At 12, at the time of my first encounter with string theory, I thought physics could answer all questions that I had about the universe. But now I understand that many of them may remain open forever, in particular the more philosophical ones, such as: what happened during the big bang? Was there something before it? What exactly is time, and why is it inevitably flowing in one direction? Where does all the matter come from? And what is it made of?
There are of course many other, more accessible, problems that I would like to see solved. For example, I have dedicated quite some time to studying string theory, so at some point I would like to know if it really is the theory of everything that we have been looking for, reconciling general relativity and quantum mechanics. Then, some string theorists assume that we have supersymmetry: for every particle there is a superpartner. Will the LHC discover these new particles in the future? A very trendy question is also if we can build a quantum computer, and if this will lead to drastic improvements of our computing capabilities. I hope these questions will get answered during this century, and who knows, maybe I can even contribute to solving some of them...

Definitions:

- **Anti-de-Sitter (AdS) space:** The maximally symmetric Lorentzian space of constant negative curvature. It is the Lorentzian version of the hyperbolic space. It is a solution of Einstein's equations of General Relativity with no matter and negative cosmological constant.
- **Quantum group:** A Hopf algebra that depends on a parameter *q* and which becomes the universal enveloping algebra of a Lie algebra in the undeformed *q -> 1* limit.
- **Weyl invariance:** invariance under Weyl transformations, corresponding to a local rescaling of the metric tensor. In the context of string theory, Weyl invariance ensures that the theory is consistent at the quantum level.

Interviewed by Elise Raphael
UniGE

Presenting the SwissMAP

Master Class 2019-20 in Mathematical Physics

For the third time, SwissMAP is organizing a year-long master class at the University of Geneva in the academic year 2019/2020 for master and beginning PhD students.

Participants enroll in a one-year program at the University of Geneva which started in September 2019, providing 60 ECTS credits. Participants are offered the possibility of obtaining a Master Degree from the University of Geneva by completing a Master Thesis for 30 additional ECTS credits.

The program started in September 2019 and will be completed in June 2020. 12 students from 8 different countries are enrolled in this Master Class alongside local students who were invited to attend the lectures.

On the following pages you will find an introduction to the lecturers and the students.

The Lecturers & Courses

Anton Alekseev

Quantum mechanics for mathematicians

Anton Alekseev is a full professor at the University of Geneva. His research interests include: symplectic geometry, moment theory and mathematical physics.

Johannes Alt

Random matrices and universality 2

Johannes Alt is a postdoc in the research group of Prof. Antti Knowles at the University of Geneva. His research interests are : random matrices, random graphs, mathematical physics and functional analysis.

Anna Beliakova

Minicourse "Quantum invariants of links"

Anna Beliakova is a full professor of mathematics at the University of Zurich. Her areas of expertise are topology, in particular knot theory, as well as quantum invariants and their categorization.

Nicolas Brunner

Quantum information theory

Nicolas Brunner is an Associate Professor at the University of Geneva. His research interests are: quantum information theory, foundations of quantum mechanics and quantum thermodynamics.

Hugo Duminil-Copin

Introduction to Statistical Mechanics 2

Hugo Duminil-Copin is a full professor of mathematics at the University of Geneva. His research deals with mathematical physics, probability, complex analysis and combinatorics.

Antti Knowles

Random matrices and universality 1

Antti Knowles is a tenure track assistant professor at the University of Geneva. His research lies in the areas of probability, analysis and mathematical physics.

Marcos Mariño

An introduction to topological field theory

Marcos Mariño is a full professor at the university of Geneva. His research interests include mathematical aspects of string theory and quantum field theory, topological string theory and topological quantum field theory.

Stanislav Smirnov

Random growth and Loewer evolution

Stanislav Smirnov is a full professor of mathematics at the University of Geneva. His research focuses on the fields of complex analysis, dynamical systems and probability theory.

Vincent Tassion

Minicourse "Percolation Theory"

Vincent Tassion is an assistant professor at ETH Zurich. His research interests are in the mathematical study of questions arising in statistical mechanics, and more precisely in percolation theory.

Amanda Turner

Random growth and Loewer evolution

Amanda Turner is a senior lecturer in Mathematics and Statistics at Lancaster University. Her main research area is in probability with a specific focus on scaling limits of stochastic processes.

Yvan Velenik

Introduction to Statistical Mechanics 1

Yvan Velenik is a full professor of mathematics at the University of Geneva. His research interests lie mainly in the applications of probability theory to the study of rigorous classical statistical mechanics, especially lattice random fields and random walks.

The Master Classes are filmed and are available online through our SwissMAP website in the videos section.

Full list of courses:

Fall:

- Quantum mechanics for mathematicians (*A. Alekseev*)
- Random matrices and universality 1 (*A. Knowles*)
- Introduction to Statistical Mechanics 1 (*Y. Velenik*)
- Random growth and Loewer evolution (*S. Smirnov and A. Turner*)

Zurich:

- Minicourse "Percolation Theory" (*V. Tassion*)
- Minicourse "Quantum invariants of links" (*A. Beliakova*)

Spring:

- Introduction to Statistical Mechanics 2 (*H. Duminil-Copin*)
- Random matrices and universality 2 (*J. Alt*)
- An introduction to topological field theory (*M. Mariño*)
- Quantum information theory (*N. Brunner*)

From left to right: Prof. Anton Alekseev (SwissMAP Deputy Director), Elise Raphael (SwissMAP Scientific Officer), Ana Roldan, Sofia Amontova, Pascale Voegtli, Claudia Rella, João Maia, Tatiana Tikhonovskaia, Ilya Losev, Vladislav Guskov.

The third SwissMAP Master Class 2019-20 welcomed 12 international students, hand-picked by our committee based on their academic skills, knowledge and achievements.

The students come from a variety of countries: Brazil, China, Colombia, Ecuador, Germany, Italy, Russia and Switzerland.

We welcome this year's Master Class in Mathematical Physics students:

Sofia AMONTOVA

Sofia is from Germany and did her studies in mathematics at the University of Bonn and Campus Pierre et Marie Curie at the Sorbonne University. For her master's thesis project she worked on random surfaces of high genus. Her interests lie in hyperbolic geometry, Teichmüller and moduli spaces, low-dimensional topology and geometry as well as global analysis.

Haihua DENG

Haihua comes from China. He graduated from Sun Yat-sen University in Guangdong Province with a Bachelor's degree in Mathematics and Applied Mathematics. He is interested in number theory and some mathematical models.

Dmitry GRINKO

Dmitry comes from Russia. He was a prize winner in the Russian Physics Olympiad in high-school, he finished Moscow Institute of Physics and Technology with distinction before he got an Excellence Scholarship to study at ETH Zurich. Dmitry currently holds a Master degree in Physics from ETH Zurich. His research interests are in mathematical aspects of quantum information, statistical mechanics and condensed matter physics.

Vladislav GUSKOV

Vlad comes from Russia. He studied at the Moscow Institute of Physics and Technology where he received his Bachelor diploma with honors. As a bachelor student, he contributed to two journal papers in Quantum Field Theory. Currently, his interests include theoretical research in statistical mechanics as well as other topics in mathematical physics.

Ilya LOSEV

Ilya comes from Russia. He obtained his bachelor's degree at the Saint-Petersburg State University and works there at the Chebyshev Laboratory. He is studying problems related to complex analysis, probability theory and mathematical physics.

The Students

João MAIA

João comes from Brazil and is currently a PhD student in applied mathematics at the University of São Paulo. In his research and studies, he is mainly interested in statistical mechanics, more specifically on problems involving large deviation and phase transition on trees.

Tomas MEJIA GOMEZ

Tomas was born in Colombia and obtained his Bachelor's and Master's degrees from Universidad Nacional de Colombia, at Medellin. In 2018 he moved to the US to start his PhD at Johns Hopkins University. Tomas is interested in topology and its interactions with geometry and mathematical physics.

Claudia RELLA

Claudia was born in Rome, Italy. She obtained the BSc in Physics from Sapienza University of Rome in 2018 and the MSc in Mathematical and Theoretical Physics from University of Oxford in 2019. Among her research interests are random matrices and applications of algebraic geometry to QFTs.

Ana ROLDAN

Ana was born in Ecuador. She obtained an Excellence Scholarship for her undergraduate studies. She received her Bachelor in Physics from EPFL. She is currently finishing her Masters in Physics at ETH Zurich, where her topic of research is BF Theory and Topological Gravity. While studying in Lausanne, she shared her passion for Physics and Mathematics via her work as a teaching assistant and President of the Young Physicists Forum, to inspire other students and support them with their studies.

Benjamin STRITTMATTER

Benjamin is from Germany and was educated at ETH Zurich and Imperial College London. He has a broad experience in research, beginning as an undergraduate researcher in black hole astrophysics. His interests evolved towards cosmology and in particular field-theoretic generalisations of gravity. Currently, he is concerned with the mathematical intricacies surrounding approaches to quantum gravity.

Tatiana TIKHONOVSKAIA

Tatiana comes from Russia and is currently a master student in physics at the St. Petersburg State University. During her bachelors work, she studied integrable systems at the Steklov Institute for Mathematics in St. Petersburg.

Pascale VOEGTLI

Pascale comes from Switzerland. She graduated from the University of Basel in Mathematics and Physics. Her main interests lie in algebraic geometry and topology.

The Master Classes have proven to be a highly successful way of attracting talented young students to Switzerland, with about 20% of them enrolling for a PhD with a SwissMAP professor upon finishing the programme in each edition.

Students from more than 15 different countries have participated and SwissMAP has provided scholarships to some of these carefully selected students. Applications from female candidates have been strongly encouraged and the committee has ensured gender balance.

All participants are integrated at the start of the programme to the SwissMAP network and encouraged to take part on other activities too, such as the annual SwissMAP General Meeting, the Winter schools and other SwissMAP seminars.

Previous Master Classes:

September 2015 - June 2016

Master Class in Planar Statistical Physics

Participants: 12 students from 8 different countries, 50% men 50% women

September 2016 – June 2017

Master Class in Geometry, Topology and Physics

Participants: 18 students from 10 different countries, 59% men 41% women

September 2019 – June 2020

Master Class in Mathematical Physics

Participants: 12 students from 8 different countries, 58% men 42% women

Student Interviews

Following the successful launch of the third SwissMAP Master Class, we decided to sit down with three of our current Master Class Students: Vladislav Guskov (VG), Tatiana Tikhonovskaia (TT) and Ilya Losev (IL) and talk about their studies and plans for the future.

What initially attracted you to the SwissMAP Master Class?

(VG) *A couple of things. First, it is a unique programme with outstanding lecturers. Second, it was a personal challenge. I came from physics and my mathematical education was not that advanced. So, I wanted to change it.*

Vladislav Guskov

(TT) *I first heard about this programme from my friend who participated in a previous SwissMAP Master Class three years ago. When I found out about this year's programme I was very interested in the subjects and I also wanted to change from where I was studying.*

(IL) *In my previous University in St Petersburg, I studied complex analysis where I learnt about statistical mechanics. I found this Master Class interesting as it offered great insight into modern research in this area.*

Was the level and content as you expected?

(VG) *Even better than I expected. All the topics were introduced from scratch. This approach serves people with a different background and I could easily catch up.*

(TT) *Perhaps there are less courses than I had thought there would be. As for the content, I was initially afraid that my level of mathematics would not be enough. After the first semester exams, I realized that there is nothing you can't do if you attend all the classes and practices.*

(IL) *Yes, I expected the highest top level education. In terms of content, some parts were unexpected as some courses were more geometric. Being less familiar with geometry and algebra for me it was very interesting to discover other areas.*

What have you so far found most challenging?

(VG) *The work on a master project. There is a lot of independent work: a supervisor gives you hints how to tackle a problem but still you need to go through many research articles on your own and come up with ideas for your problem. I think this approach is a good one at this point because it helps to understand if research in mathematics is your thing or not.*

(TT) *I think the most challenging thing was the exam session because it is quite different from Russia. I was expecting all exams to be written but I had only one written and 3 orals. I was particularly nervous because my previous experience of exams was very different.*

(IL) *Probably courses that require some concepts from geometry and algebra that I do not know much about. It made it harder to follow.*

And the most enjoyable?

(VG) *People, of course. The interaction with professors and classmates was the most enjoyable and valuable part.*

(TT) *I think people are the best thing at University. Both lecturers and students, it is really pleasant to be amongst people who are really interested in mathematics.*

(IL) *To see how my background in*

Tatiana Tikhonovskaia

complex analysis could help to solve really beautiful problems.

Can you cite one special moment?

(VG) *I'd like to mention special attitude of Prof. Anton Alexeev. Besides well prepared lectures on Quantum Mechanics, he also devoted a lot of his own time to be present at exercises sessions and our student seminar helping out with solving problems and giving valuable comments. That is really appreciated.*

(TT) *I thought I knew quite a lot about the Quantum Mechanics lectures as I had already studied the subject before but it was great to find out that there is so much more in this field than I thought.*

(IL) *For me, it was surprising to see that in many of the courses in the end, professors were able to prove their own theorems. This is not always the case in other universities, especially at master level.*

How did you find the structure of the course?

(VG) *All courses were well balanced: 2/3 theory and 1/3 exercises which I think is a really good proportion. Moreover, we had opportunities to participate in the conferences organized by SwissMAP. The organization of both the conferences and the educational process was the best in my experience.*

(TT) *One hour seems to be very little time for the practice, I feel there could be more time.*

(IL) I think it was well organized because some courses require some background and this background was provided before. Like for example for quantum information theory, quantum mechanics was explained to us before.

What is your research area of interest?

(VG) *Generally speaking, it is statistical physics and things around it. At the moment I am working on Bethe Ansatz with application to the Heisenberg spin chain. I am also very interested in random growth models and Schramm-Loewner evolution.*

(TT) *In Geneva I started working on Statistical Physics but I expected something a bit different from what I am doing…*

(IL) *Statistical mechanics.*

Has the Master Class helped to define or confirm your research area of interest?

(VG) *Yes, indeed. The Master Class helped me understand that my interests align more with a mathematical approach to solving problems.*

Ilya Losev

Before the programme, my aim was to develop mathematical skills but still continue with research in physics. Now I am quite certain that research in mathematics is the way to go.

(TT) *Although I am enjoying Statistical Physics, I think for my PhD I will do something different.*

(IL) *It has helped me to confirm that statistical mechanics is the area that really interests me.*

And what about influenced any decision(s) concerning your future plans? If so, how?

(VG) *Truth is, this programme made major adjustments in my plans. Due to the course by Stanislav Smirnov and Amanda Turner last semester I got to know a beautiful area of Schramm-Loewner evolution and random growth models and now I am going to do a PhD in this subject.*

(TT) *For me it's a difficult question because I am going to change fields…*

(IL) *It has helped me to confirm that Statistical mechanics is what I want to do in the future.*

What are your current & future plans?

(VG) *I am going to Stockholm to start my PhD at KTH with Fredrik Viklund. Our first project will address Schramm-Loewner evolution and I look forward to it.*

(TT) *I'm going to stay in the University of Geneva in Antons Alekseev's Group.*

(IL) *I want to continue with research. After the Master Class, I will return to St Petersburg to finish my Master's there, because the programme there is for two years. After that, I will certainly continue with a PhD.*

Interviewed by Mayra Lirot
NCCR SwissMAP

The Master Class Alumni Series

Interview with **Benjamin Hoffman**

Master Class in Geometry, Topology and Physics 2016

For SwissMAP it is important to keep closely connected with alumni, we strongly value this relationship and encourage our alumni to remain as part of the SwissMAP network.

Our alumnus Benjamin Hoffman speaks about his experience as a SwissMAP Master Class student of the second Master Class series in 2016 and how the Master Class helped him.

You finished a B.A. in Mathematics and Philosophy at the Lewis and Clark College before joining the SwissMAP Master Class in Geometry, Topology and Physics in 2016.

Can you briefly tell us about what initially attracted you at that time, to the SwissMAP Master Class?

I was not the typical Master Class student as I was also enrolled at Cornell University in a PhD programme at the same time. I heard about the SwissMAP Master Class in Geometry, Topology and Physics in 2016, through one of the Professors at Cornell who knew of my interest to study in Switzerland. I was very attracted to the Master Class as it offered a great opportunity to learn more about the subjects that I was interested in.

Did the Master Class help you to define or confirm your research area of interest?

For me it was also important to focus on research as well as the Master Classes, so I asked Anton Alekseev if there were any ongoing projects and he gave me a problem to work on. I worked on it with Anton and one of his graduate students Yanpeng Li. We wrote a paper as a result of it and have continued the collaboration since…

Can you cite one special moment?

For me, the collaboration with Anton Alkeseev has been a really important and a long lasting part of my career and has also defined my PhD. The collaboration has continued and we are currently writing our fourth paper together.

Can you briefly tell us what your current research area of interest is?

I'm interested in building a bridge between two areas, one is the study of canonical basis and representation theory and the other is focused on Lie theory and Hamiltonian mechanics.

What are your future plans?

I defended my thesis in April this year at Cornell. I will start a Postdoc at the University of Toronto which I am very excited about.

Interviewed by Mayra Lirot
NCCR SwissMAP

Presenting the:
ETH Math Youth Academy

- **Student:** *"If the exponent were a prime, the proof would be complete. Can we prove that it is prime?"*
- **Instructor:** *"I absolutely agree with the first part."*
- **Another student:** *"But we can assume without loss of generality that it is prime, so we are done!"*

This is a typical snapshot from a class at the ETH Math Youth Academy. Motivated and talented students between the ages of 13 and 19 come to ETH once a week to engage in difficult extracurricular mathematics. The focus is on creative, out-of-the-box thinking and rigorous proofs.

The inspiration for designing and launching the program in 2015 was the fact that even though Switzerland consistently ranks high in PISA studies measuring the average level of mathematical education in schools, opportunities for the best students did not abound, at least in comparison to other countries (in Eastern Europe or the US, for example). Our goal has been to fix this gap.

We started in 2015 with a total of about 10 students across all 3 levels. The participation rate has been growing with steady pace, and now about 25-30 students take part in the level for first-year participants and about 10 in the intermediate and advanced levels. Some students even attend multiple levels in parallel. There is no formal credit associated with the classes - students attend entirely for their own fulfilment and intellectual satisfaction. Some students commute from outside of canton Zurich - for example, from Bern, Thun, or Luzerne, and one student even takes the train from Lugano. They are passionate for opportunities to do mathematics beyond what the regular school curriculum has to offer.

Kaloyan Slavov with students of the ETH Math Youth Academy. Source: ETH Math Youth Academy

ETH Zurich Campus. Source: ETHZ

The course for first-year students is a survey of a broad range of topics, with 2-5 weeks devoted to a single topic. These include: mathematical induction, the Pigeonhole principle, and invariants. An advanced number theory course may start with Gaussian integers and reach difficult Diophantine equations (for example, Fermat's equation with exponent 3). We illustrate even the more theoretical topics with an abundance of vivid and nontrivial problems. An intermediate geometry course would start with cyclic quadrilaterals and reach the theorems of Ceva and Menelaus, homothety, and power of a point. An advanced Euclidean geometry course would focus on trigonometry techniques or on inversion. An intermediate or advanced combinatorics course may discuss generating functions and other enumerative techniques, again with plenty of applications. In an advanced algebra course, we prove various criteria for irreducibility of polynomials. We do not touch standard topics that a mathematics major would later learn in a university. The curriculum is designed so that a student can participate over the course of up to 4-5 years and delve deeper into more sophisticated mathematics.

I have developed an interactive lecture format of teaching namely, students participate actively in solving the problems, while I guide them in the process. In this way, I reach a balance between on the one hand allowing them to work independently and to arrive at the solutions themselves, and introducing new material and reaching harder topics on the other. In order to introduce new ideas or to present problems that are difficult for the students at the current stage, I start the discussion, let them brainstorm ideas or proposals, and then give them hints or highlight the proposed ideas that they can develop further. We have videotaped a number of public talks given at various schools that illustrate my interactive lecture style and teaching philosophy; these also give a good idea of how an ETH Math Youth Academy class looks like. By now, we have built a rich database of videotaped material, which can be found under "Public Talks" on the program's webpage: https://www.math.ethz.ch/eth-math-youth-academy.

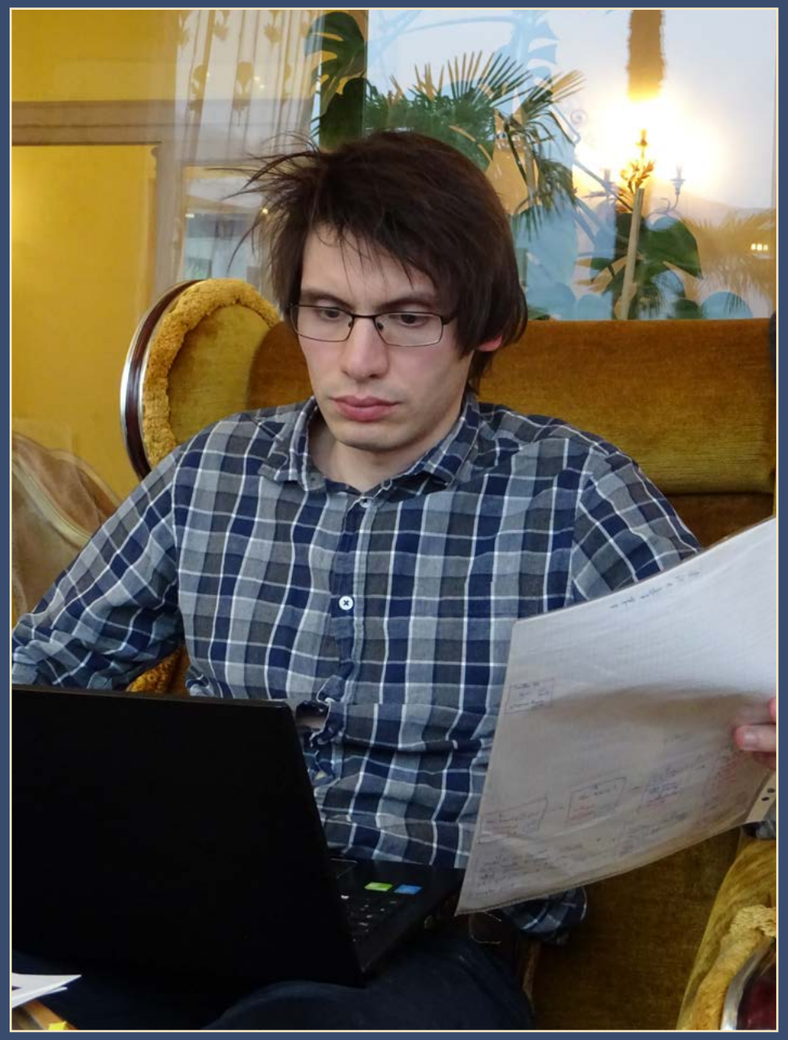
While not the only goal, preparation for mathematical olympiads is a focus of the program. Out of the 6 best scores at the preliminary round of the 2020 Swiss Math Olympiad, 2 are regular participants in the ETH Math Youth Academy. One of them in fact got a perfect score and the other has the highest score among girls, thus qualifying (for a second consecutive year) for the upcoming European Girls' Mathematical Olympiad. Also, 7 of our students are in the top 22. The performance in the Final Round this year was similar: 2 of our students are in the top 6 and 5 in the top 14. It is impressive to watch the growth of our students over the years.

Author: Kaloyan Slavov
ETH Zurich

SwissMAP stories:

Alumnus - Fathi Ben Aribi

Research & Outreach



I was born in Paris, France, and I did most of my studies there. As far as I remember, I have always been interested in mathematics. One of the things that I enjoyed most about mathematics at school was that an answer was either true or false, and thus the grade could not vary according to the teacher.

I think of mathematics as a language.

I think of mathematics as a language. Most people see mathematics as a set of tools to solve problems and that is not the full story. Obviously, it is a *part* of it, but at its core mathematics is a language. Math is a way to model abstract thoughts or objects of real life, which enables us to give them precise definitions and *only then* to work with these objects (perhaps to solve real-world questions).

I went to the École Normale Supérieure in Paris (ENS), where I completed a Bachelor and a Master in mathematics. I had always considered the option of becoming a full-time math teacher, but after my Master's thesis it was clear to me that I wanted to continue doing some research. I did my PhD in Université Paris 7 and from there I moved on as a postdoc in UniGE. I currently have a postdoc position at UCLouvain in Belgium, where I plan to continue and finish some of my previous research projects. In the long term I would like to get a permanent position as a researcher, with or without teaching (which I always enjoy in conjunction with research).

People often ask why I study mathematics, if all the theorems have been proven… Far from it! In fact, you can always find more questions, there is always new ground to discover.

My main research subject is topology. Topology consists in studying objects up to deformation as if those objects were made of modelling clay. In this sense, a ball is the same as a cube because you can deform one shape into the other. Topology is really fun because it is quite visual: you can draw pictures to understand why one object is actually the same as another object (up to deformation). More precisely, my research focuses on *knot theory*, which is the study of knots as mathematical objects. Yes, just what you might expect, these are the knots you obtain by tying up a piece of rope. You might then like to know if the knot you just tied is *actually knotted* or if it becomes undone if you pull on the rope in a particularly smart way. You might also wonder if one knot is actually the same as another knot (up to deformation of the rope keeping its endpoints fixed in your hands), which in turn would allow you to *classify* knots. Such a classification is the original main goal of knot theory.

One might ask, why would anyone want to do this? In mathematics there are questions that arise in an abstract way. How can we define a pretty common object such as a knot? How can we describe them and identify them? What should we name them? That is the basics of mathematics, just to look at an object or theory and make sense of it. Knot theory was founded by Lord Kelvin, a physicist who conjectured that atoms and molecules were actually knots in an underlying "aether". Hence, in order to classify atoms, he needed to classify knots. This knot classification was then begun by Tait, a mathematical physicist. More than a century after, knot theory finds applications in many branches: biology, physics, chemistry, for example via the study of knotted molecules.

In SwissMAP, I was a postdoc at UniGE in Rinat Kashaev's group in quan-

People often ask why I study mathematics, if all the theorems have been proven… Far from it! In fact, you can always find more questions, there is always new ground to discover.

tum topology, a branch of topology related to knot theory.

I found that SwissMAP offered a lot of opportunities, which I always appreciated. They notably organized several events, which led to many fruitful discussions and getting to know new people. Also, the SwissMAP Master Classes offer a great opportunity of high-level but still introductory courses.

I really appreciated my time in the math department at the University of Geneva. The atmosphere there was really nice, everyone felt welcome, from first-year students to emeritus professors.

Outreach

My experience with outreach in Geneva began when I helped out for the *Nuit de la science* in 2016 (an event for the general public). Afterwards, I worked with the Mathscope, by giving weekly one-hour long workshops for audiences ranging from 4 to 18 years old. Most of the workshop content was already created and was done in such a way that sometimes the children didn't even realize that they were doing maths! Unfortunately a lot of people have negative biases about mathematics, for various reasons. For instance they might think: mathematics are not for me, they are too hard, they are boring. Thus, a nice trick we used in the Matshcope was to introduce pupils to an idea without saying it was mathematical.

I think the Scienscope is an exceptional part of the University of Geneva and thus needs to be preserved. Financially and logistically speaking, I have not seen support of such scale for an outreach department in other universities. I really enjoyed being part of Scienscope, and I hope that it will live on and keep bringing joy and understanding to many young students.

In SwissMAP, I was a postdoc at UniGE in Rinat Kashaev's group in quantum topology, a branch of topology related to knot theory.

On stage

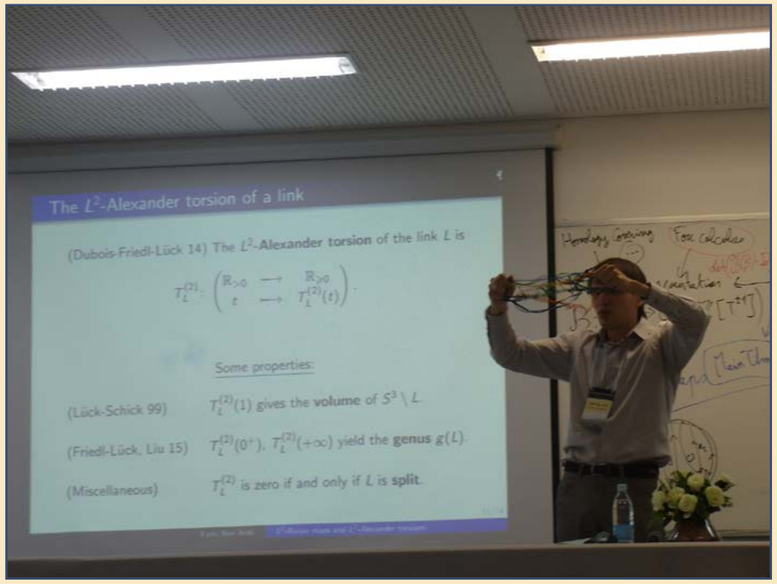
In Geneva I also had the opportunity to write two theatre plays for scientific outreach.
The first one, called *Le nœud du mystère*, was 10 minutes long and was made for the *Nuit de la science* 2018. In this play, a crime is solved thanks to mathematics (more precisely knot theory, hence the title). I wrote and directed and my two colleagues Guillaume Bertoli and Adrien Laurent carried it brilliantly on stage. Subsequently, I had the opportunity to write and perform a second longer play (one hour long), called *Mystère au Manoir Moutarde*. It was made in collaboration with the Scienscope for a project of the Public Instruction Department. Again, there was a mystery that science helped to solve, but this time mathematics teamed up with physics, chemistry, computer science and biology. The detective in the play was able to solve the mystery via fun scientific experiments, that the audience members could try themselves later at the Scienscope. Since the play was written for 10 to 11 years old kids, we really wanted to present science as a means to make possible what one would have usually considered impossible, like seeing DNA with the naked eye. Furthermore, the fact that science proved useful to solve a mystery is related to the more profound idea that one of the goals of science is to get closer to the truth.

For those considering mathematics...

The main difference between mathematical research and mathematical studies is that in the studies you learn things that have already been discovered, mastered and refined, whereas in research you need to create something new. Mathematical research requires intuition and understanding of how things work together and are related to one another. In a way, mathematical studies could be compared to learning a new language and mathematical research to writing novels in this language.

The personal qualities that have helped me to study mathematics are a good memory and the fact that in general I like things to be ordered. I think that one of the positive consequences of studying mathematics is introducing order in your mind, which can help you express an idea in an explicit way and state a problem in a non-ambiguous way. Math is about knowing how to talk, discuss and think logically.

This might sound obvious, but I think that if you want to do long-term math studies, it's better if you fundamentally enjoy mathematics. It is not a necessary condition, but if you find math fun it is already a good sign for following this path!



Author: Fathi Ben Aribi
UCLouvain

Presenting:

SPRING

(SwissMAP Programme for Reading IN Groups)

SwissMAP is proud to present its new one-semester long programme SPRING for high school students who want to take their interest in mathematics to the next level. SPRING is available in both Geneva and Zurich, and is open to successful Athena and ETH Math Youth Academy participants.

Guided by a tutor (master student, PhD candidate or doctor in mathematics), students work in small groups of maximum four participants. A weekly meeting is the occasion for each individual to present and explain his/her reading to the rest of the group.

The semester ends in June with a group presentation of about 30 minutes to other SPRING participants from both Zürich and Geneva. Students who successfully follow the SPRING programme will be granted a SwissMAP certificate of participation.

In 2020, two groups of students (each consisting of two participants per group, 1 girl and 3 boys) are currently taking part in the SPRING programme in Geneva. One of them is working in topology: their goal is to understand the theorem of classification of surfaces. The other is working towards building the mathematical background necessary to work on neural networks and machine learning.

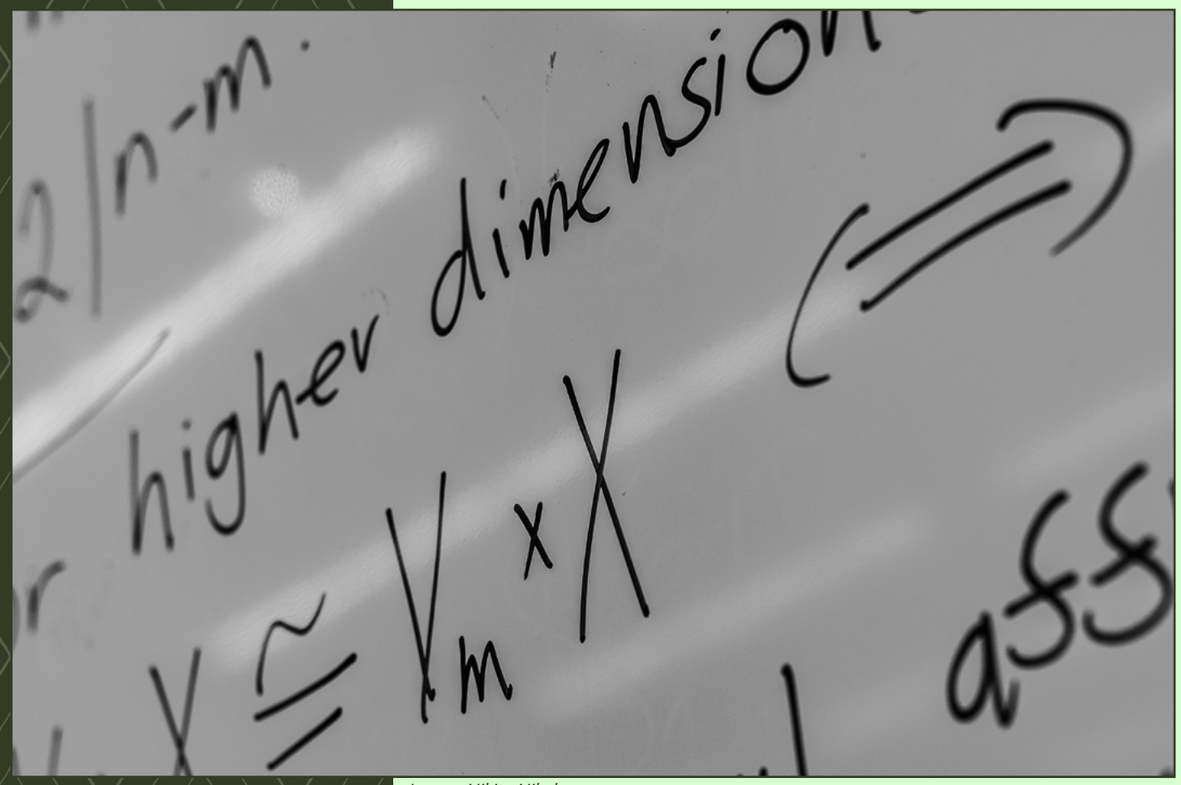


Image: Nikita Nikolaev

ATHENA is a UniGE based programme aimed at students interested in physics and mathematics and in their final two years of high school. The programme provides them with the chance to attend first year university classes in a supported environment.

Since 2015 SwissMAP has supported this initiative and we are proud to announce that 5 former Athena participants from the first ever Athena session, received their Bachelor in Mathematics from UniGE last year.

We spoke to one former and two current Athena participants who have shared their experience.

ATHENA interviews:
Sylvia and Tran
Current students

From left to right: Tran and Sylvia. Current Athena students.

- When and how did you first hear about the Athena programme?
Sylvia: *2 years ago, from my physics teacher, also a friend of ours participated which allowed us to learn more about it.*

Tran: *I'm in the same class as Sylvia so it was the same for me.*

- Why were you interested in it?
Sylvia: *I just love participating in activities where I can learn things.*

Tran: *I think it's a great opportunity to get a glimpse of math classes at university. It's always good to see what's waiting for you if you choose the scientific path.*

- How long did you participate?
Sylvia: *1 semester for 2 years.*

Tran: *Yes, we chose Math methods for physicists the first year and Logic and introduction to Set Theory the second year.*

- Was the level and content as you had expected?
Sylvia: *Yes and no. I did expect it to be hard, but I didn't expect the sort of curve that happens in almost every class, where the class starts with something basic enough, that I can totally understand, and then in a few minutes, becomes something complicated. I need time to wrap my brain around it.*

Tran: *It's the same for me. It always surprises me how in one class, university students can learn about a topic that high school students need a month to grasp. So, in the end, I guess I didn't learn as much as I expected during the Athena programme, not because it is not interesting, but because many things were too advanced for me.*

- What did you enjoy most about the programme?
Sylvia: *Seeing what university lectures were like, experiencing university life in general, and meeting new people.*

Tran: *One of the great things about this programme is that we have a study session with a Master/PhD student every week where we can ask questions. Our tutor, Charlotte, is very passionate about maths and has helped us a lot.*

- How did you find the structure of the course?
Sylvia: *I liked how every class was focused on one aspect of the subject, that there's a beginning and an end. Also, during the second class, there were shorter, but more frequent breaks, which I also liked. I think that, in a field such as mathematics, it's very hard to only listen to theory for two hours straight.*

Tran: *I guess it's the same for me.*

- Why do you like maths / physics?
Sylvia: *I love maths because learning it is like learning a language, like you are part of a secret club where only the members know this secret language. I love all the symbols and how they can be keys used to solve problems that are both trivial and extremely complicated. I love physics even more because I get to understand how the world around me works and it's simply fascinating.*

Tran: *I like maths because unlike many subjects, it is very straightforward. In maths, something is either true or false. When you finish a maths test, based on your answer, you can immediately predict your grade. Whereas with subjects like literature or philosophy, many things you said can be right, wrong or somewhere in between, depending on the point of view. For physics, I just believe that learning about physics makes you understand how things work and that, can make your life way easier. Personally I think it is the most useful subject I learn at school.*

- What are your current & future study plans?
Sylvia: *Right now, I am in the physics and maths option at college, but a few months ago, I got an offer from Cambridge to read Education and another one from UCL in London to study Arts and Sciences, so I would take classes in Physics and History of art, Film, Philosophy and English Literature. So, Plan (A) is Cambridge and plan (B) is UCL. Even though my studies now don't correspond to those I will be doing next year, I don't regret them at all. I have learned so much, and I think these are things that everyone should know!*

Tran: *I am also in the physics and maths option. I plan to study Life sciences at EPFL next year because I've always been fascinated by the connection between maths, physics and biology. I also like the idea of working in a domain related to living creatures more than pure maths and physics. It is perfect that I study math and physics in high school, because even though the classes will then be more biology oriented, maths, physics and programming will still be the base and tools to everything.*

- Would you like to follow an academic path?
Sylvia: *Of course! I'm planning on getting a PhD, though I don't know in what yet…*

Tran: *I just want to do what interests me at the moment. I like the idea of studying for as long as possible and having at least a PhD. But anything can happen in the future and I might change my mind, so there's no point thinking about it now.*

Conversation with two current Athena students

Interviewed by Mayra Lirot
NCCR SwissMAP

ATHENA interviews:
Ekaterina Golubeva
Former student

Ekaterina Golubeva. Former Athena student.

- When and how did you first hear about the Athena programme?
I first heard about Athena during a Mathematics class in high school in 2016, one year after the programme was launched. My math teachers encouraged me to join the programme.

- Why were you interested in it?
I was able to discover what the University looks like while still in high school. This was a unique occasion for me at that time; to see where I would be studying later on.

- How long did you participate?
I followed the one-semester course of Géométrie I *in Mathematics and, the following year, I took another semester in a Physics course, called* Mathematical methods for physicists. *In short, I participated twice.*

- Was the level and content as you had expected?
I had no expectations at the beginning, it was all new to me. I was conscious that it was going to be harder than in high school but the programme actually started with the basics (e.g. Euclid's Elements*) and I was able to keep up and follow the programme without much difficulty. And when it was getting harder sometimes I had a tutor who helped me with assignments and who helped me understand the lectures.*

- What did you enjoy most about the programme?
During the programme I discovered a different aspect of Mathematics, one that we don't learn at school. I discovered its beauty and fell in love. I remember what absolutely fascinated me when I first learned about non-Euclidean geometries: the hyperbolic tiling of the Poincaré disc. I also heard about complex numbers for the first time in the Géométrie I *course.*

What was even more engaging was being coached by a tutor. I was surrounded by people who were writing their PhD thesis and they used to talk about their research areas with such passion that it encouraged me to try and also find my own passion. Since then I decided that I would also want to find some area where I could solve a question or help a further understanding of a topic. I really enjoyed the stimulating environment I was in and I thank everyone who contributed to it.

- Did the programme help you to confirm your interest in physics and in Mathematics?
It was definitely the trigger for me to choose to pursue my academic path in Mathematics.

- Why do you like maths / physics?
I firstly fell in love with Geometry, shapes and symmetries. Then I realized everything in maths was about patterns and structures. I love math for its inner beauty, mystery and for its sense of fulfilment and satisfaction. In moments when I get to understand a topic or solve a problem I feel like it's worth it.

Ekaterina Golubeva. Former Athena student.

"Mathematics is a language in which God has written the Universe" said Galileo and I recognize in it a unifying entity. With its universal language maths unite men and women, nations and cultures and I find this really wonderful.

- What are your current & future study plans?
At the beginning of this academic year I was trying to launch a start-up (called Mathbridge) and I have chosen to extend my Bachelor's to 4 years to be able to develop the project besides my studies. I had to stop my entrepreneurship activities temporarily, but I prefer to keep the current rate (i.e. taking half of the classes). I now can go back to savouring Mathematics with less pressure due to exams or deadlines. I have reduced my anxiety and I can study my current subjects much deeper.

- Would you like to follow an academic path?
I would love to try working in the field of research if one day I get the chance to do so. However, I'm not against the idea of working for industries, in the fields of applied Mathematics as well as in scientific communication or popularization. I'm open to new opportunities. I still have so much to learn and to discover in the different fields of maths. I would love to be helpful and share all the knowledge, passion and enthusiasm with people as much as I can. The idea of popularizing Mathematics inspires me. I like making it more accessible to people who may struggle with it. My project and my tutoring allow me to convey some of the meanings and insights that I can access, because I have the chance of studying it deeply. I am really grateful for that.

Conversation with a former Athena student

Interviewed by Mayra Lirot
NCCR SwissMAP

Presenting:

The Maths Club

SwissMAP has supported the activities of the University of Geneva's Maths Club (*Club de Maths*) since the start of the NCCR. This is an extracurricular activity in Geneva for 10 to 16 years old students. This year, there were 34 participants divided into 4 groups.

An enthusiastic team of bachelor and master students, working with SwissMAP Outreach Officer Shaula Fiorelli, welcome participants for two hours per week throughout the academic year, which they alternate between sessions of problem solving and small group activities.

The main goal of the *Club de Maths* is to stimulate the participants' intuition and mathematical curiosity. Topics are very different from those covered at school and the approach also differs: there are no assignments or exams. Our approach aims at being recreational, so that participants can develop a real pleasure in doing mathematics.

Every year a *Mathematical Olympiad* is organized: students work on a set of problems (depending on their age group) for 4 hours. An award ceremony is later held in presence of all *Club de Maths* tutors and the SwissMAP Outreach Officer.

One of the small group activities proposed by *Club de Maths* is dedicated to introducing the basics of knot theory. The central idea is to immerse children into some exotic mathematics, very different from what they experience at school. This activity takes place over three weeks. Here is the activity walk-through presented by its creator Terence.

Students are first given the material (knots made of iron wire and electrical cables) without any instruction and can freely manipulate the different objects. Once they are a bit familiar with it and the excitement of discovery is vanishing, it is time to ask them the first question: "What is this?"

Once the word "knot" arises (or is elicited from students if necessary) and is given as the name of such objects, the next question is asked: "How can one differentiate these objects quickly?"

Different criteria are listed at the board by students with the help of tutors, and the word "invariant" is introduced.

Once all the ideas have been gathered, it is time for a little history of the subject and possible applications to real life.

Then, we focus on the challenge at the heart of knot theory: being able to tell one knot from another with certainty. Students quickly realize that it is very hard to work with 3D knots and we teach them how to represent the objects they can manipulate via diagrams.

The main goal of the Club de Maths is to stimulate the participants' intuition and mathematical curiosity.

When students master the diagrams of basic knots and links (trefoils, figure eight, Hopf, Whitehead, unknot...), we discuss Reidemester movements. The depth of the discussion depends on the age of the students.

We then go back to the list of criteria proposed by the students and try them on diagrams: the number of crossings is eliminated from the candidates.

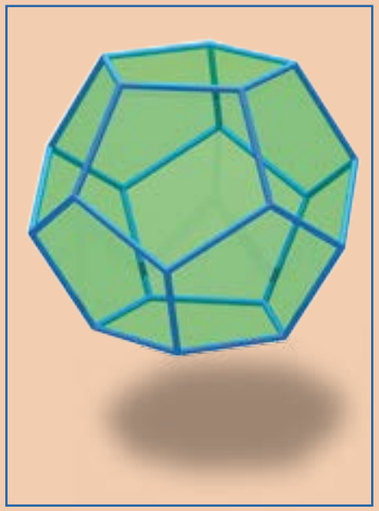
A proper definition of invariant is given and the list is generally narrowed down to the trivial invariant and the number of components. During the last session, we add the following invariants to the list:

- unknotting number
- tricolorability (and eventually five-colorability)
- linking number.

At the end, a recapitulative table is constructed with the students, stating which invariant allows to differentiate which pair of knots studied. For advanced groups, some of the following notions may be added:

- Connected sum of knots, abelian monoidal structure
- Construction of the Alexander polynomial (historical approach and using skein relations)
- Extension of knot theory to graph theory.

We present some of this year's *Olympiad des Maths* problems on the next pages.

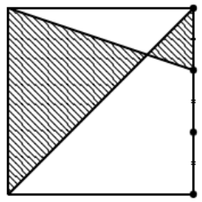


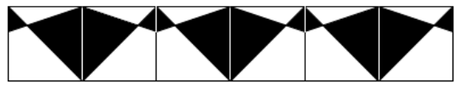
Authors: Lucia Camenisch & Terence Wenger
UniGE

Here are some of the problems from this year's Math Olympiad organised by the Club de Maths

1. Frieze Decorating

In Charlotte's class, students are using the Mathematics' week as an occasion to redecorate the classroom's walls with a frieze. The pattern they chose is made from a 21cm square as you can see below.
What is the exact area of the shaded area?

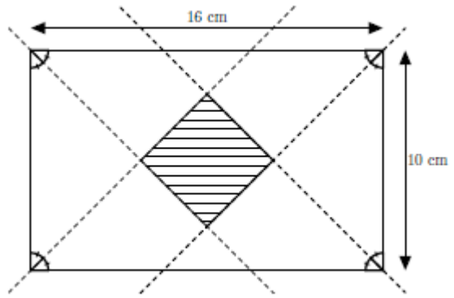




Solution: 183,75 cm²

2. Rectangle Frieze

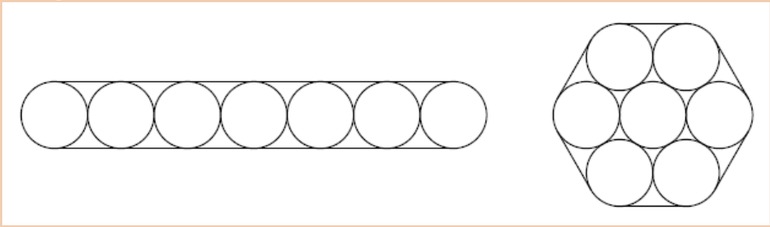
Leo's students are less imaginative: their frieze is made from the rectangle below, with all bisectors drawn. What is the area of the quadrangle obtained this way?



Solution: sixty cm²

3. Perfect Potatoes

You have found seven perfectly identical and spherical potatoes with a diameter of 3cm. This is such a rare occurence that you decide to show them in a vegetables fair, nicely tied with a silk ribbon. You hesitate between the two configurations below.
How much silk can you save (in cm) by adopting the most cost-efficient configuration?



Solution: eighteen cm

4. Blackboard Numbers

Vladimir and Lucy are both facing a blackboard on which they can read:

4 – 11 – 15 – 18 – 25

Olga randomly picks 2 of these 5 numbers, then tells Vladimir their difference and Lucy their sum.
Olga then asks:
- What are the two numbers I picked?
- I cannot know, says Vladimir.
- I couldn't know either, but since Vlad doesn't know it, now I do!

What are the two numbers chosen by Olga?

Solution: eleven and eighteen

5. The SOS Game

The SOS game is played on a 1 x 7 grid as follows:
Two players take turns writing an S or an O in one of the empty cells. The first player to complete the word SOS wins. If the grid is full but no SOS appears, it is a draw.
You are the first to play. Show that there exists a strategy allowing you to win.

Solution: Start with an S in the middle cell. You are in a winning position if this configuration is on the grid and it's the other player's turn to play: S _ _ S

Source: Rallye Mathématique d'Aquitaine https://www.math.u-bordeaux.fr/IREM/rallye/

The SwissMAP video competition launched last year, is open to SwissMAP PhD students and Postdocs who are invited to make a short video describing their research to a non-specialist audience.

The challenge is in making it accessible, interesting and fun for both the researchers and the general public.

Videos are judged on the quality of the scientific explanation as well as creativity and overall presentation.

SwissMAP PhD & Postdoc

Video Competition

First Prize: Ofir David

Researching the mathematics of billiard tables

Ofir David (UZH, C. Ulcigrai Group)

- What was your main motivation to participate in the video competition?
I actually started working on the video before I knew about the competition. The competition began at a good timing, giving me extra motivation to work on the video.

- What parts did you find most challenging in the project?
The part which is almost always the most challenging is finding a good way to present the subject. This usually starts with an idea that I think about for weeks and even months before I even begin to think about making a video. The second part is to think of a visual way to do the presentation that I could actually create in a reasonable time. Once this is done, the rest is mostly manual work of writing down the code for the animation, creating and synchronizing the narration, writing notes of the subject etc.

- What part did you enjoy the most?
Thinking about ways to present mathematical ideas is always the most enjoyable part for me. This is one of the main ways of transforming a subject that I know to a subject that I understand.

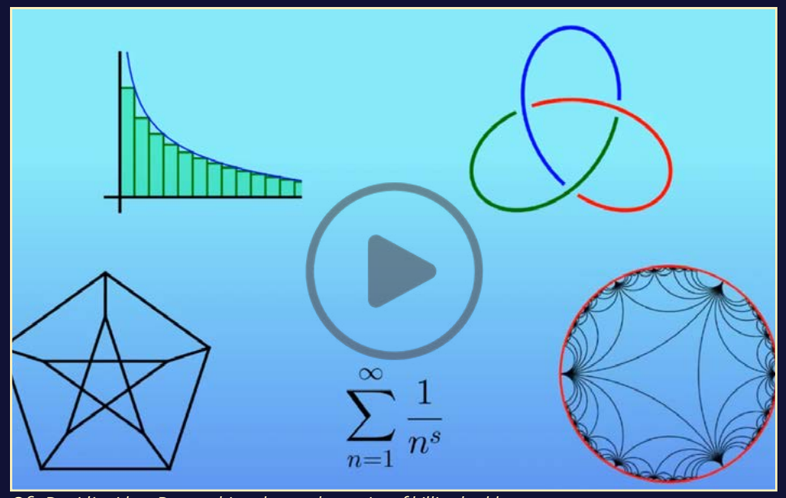
- Did you get help from other people? If so, what were their qualifications?
I created the video by myself. After I finished the first draft I got some remarks about the presentation from a couple of colleagues which I incorporated in the final version.

- How long would you say the video took to make in total?
The making of the video spread over a few weeks, though I only worked on it (namely the coding, editing, etc) a couple of hours each week.

- What comments have people made to you about the video?
I got very few comments on the video.

- What advice would you give to someone who is considering participating?
Making a video to present a mathematical idea (or in general any research area) is not an easy task. Probably the biggest obstacle that I had to overcome in the beginning is learning how to do some simple video and audio editing, since out of the whole video making process this is the one area which I had zero knowledge, and I believe that this is true for many people in the academy. If you can find someone who knows how to do this sort of stuff and is willing to help you, then you already made your first step.

There is also a big difference between presenting a subject in a video than in other settings, like a classroom or a paper. I would suggest to try and find as many people as you can to give you remarks about the video (and try to avoid experts in your field which already know everything that you are trying to present).



Ofir David's video: Researching the mathematics of billiard tables
Hosted: SwissMAP YouTube channel

Second Prize: Nikita Nikolaev

Abelianisation of Differential Equations

Nikita Nikolaev (UniGE, A. Alekseev Group)

- What was your main motivation to participate in the video competition?
It seemed like an interesting technical and artistic challenge to find a way to present something about my research in a succinct, accessible, and engaging way.

- What parts did you find most challenging in the project?
By far the biggest challenge was to come with exactly what to say, and specifically to find the right balance between clarity and accuracy. Formulating the script took a very large number of iterations, because although the ideas involved are often not necessarily complicated, explaining them requires a fair amount of language and/or other ideas. This makes it difficult to find the optimal way to convey the essence without either drowning in indiscernible jargon or turning the discussion into an interminable overlong tedium.

The abstract nature of mathematics is the chief culprit here, and some areas of mathematics suffer more than others. My area, algebraic geometry, is more towards the inauspicious end of this scale, though the geometric nature of many ideas does have some way of being malleable to visualisation. Abstractness sometimes inevitably forces you to sacrifice accuracy over clarity: you have to come to terms with the realisation that a precise and accurate message which is completely lost on the audience has no use, whilst an imprecise message with the right flavour which actually reaches the audience goes a long way.

- What part did you enjoy the most?
Designing the video and the script, finding the right and accessible words to explain the essence of the ideas, was intellectually a very fulfilling challenge. Also, editing the video was a wonderful way to let free an artistic side.

- Did you get help from other people? If so, what were their qualifications?
Yes, my wife, Beatriz, who is also a mathematician, albeit for an unrelated area. Her help was absolutely indispensable!

- How long would you say the video took to make in total?
Designing the script and the video took the longest, spread over several weeks. All the filming was done over two days, and the editing took one full day.

- What comments have people made to you about the video?
There has been an overwhelming amount of positive comments and feedback, for which I am truly thankful. Probably the most rewarding comment, which several people have made, is that watching the video they felt like they were watching a BBC documentary.

- What advice would you give to someone who is considering participating?
Clarity over accuracy. Always keep in mind your target audience.

Nikita Nikolaev's video: Abelianisation of Differential Equations.
Hosted: SwissMAP YouTube channel

Interviewed by Mayra Lirot
NCCR SwissMAP

Events 2020-21

Online Events of 2020:
Due to the unusual situation the world started living in at the start of 2020, most events of the year were transfered online or postponed to a later date. During this time, SwissMAP members were able to host a number of successful regular events online.

- Mathematical Physics Seminar (UniGE)
- Global Poisson Webinar (UniGE)
- Ergodic Theory and Dynamical Systems Seminar (UZH)
- Talks in Mathematical Physics (ETHZ)
- Strings, CFT & Integrability (ETHZ)
- [K-OS] KNOT online seminar (CNRS, UNIGE)

For more detailed information please visit our Website: https://www.nccr-swissmap.ch/news-and-events/events

Jan - Mar

2 - 7 February
Winter School in Mathematical Physics - 2020
Les Diablerets
The annual Winter School in Mathematical Physics featured mini-courses by Antti Kupiainen, Nicolai Reshetikhin, Jörg Teschner, and a Colloquium by Victor Kac.

Apr - Jun

06 - 09 September
7th SwissMAP General Meeting
Saanenmöser
The program will include: The SwissMAP Innovator Prize ceremony; talks by the Innovator Prize winners, colloquia covering SwissMAP research directions, and talks by junior participants.

05 June
NCCR SwissMAP Site Visit
Geneva
The NCCR SwissMAP Review Panel Site Visit will take place online this year.

Jul - Sep

7 - 10 June 2021
Conference in honor of J.-P. Eckmann (UniGE)
Geneva
The conference was postponed from June 2020 to the following year. This event will bring together students and close collaborators of Jean-Pierre Eckmann on the occasion of his 50 years at the University of Geneva.

23 September
Journée Georges de Rham 2020
Geneva
The conference was postponed from April to the fall of 2020. This year, the invited speakers are James Maynard (University of Oxford) and Corinna Ulcigrai (University of Zurich).

Oct - Dec

January 2021
SwissMAP Research Station (SRS)
Les Diablerets
The Station, will be based in Les Diablerets, Switzerland. The SRS will be dedicated to the organization of events in Mathematical Physics (conferences, workshops, thematic meetings).

2021

29 Jul - 07 Aug 2021
ICMP 2021
Geneva
We are happy to announce that Geneva will be hosting the next International Congress of Mathematical Physics in 2021. The event will gather world-class experts in the field.

Summer 2021
Gauge/Gravity Duality 2020
Geneva
The conference was postponed from July 2020 to the summer of 2021. The aim of this event is to explore all aspects of gauge/gravity duality, both applied and theoretical, and to generate an extensive exchange of ideas.

Awards


Alessio Figalli and Tudor Ratiu

Academia Europaea

We are proud to announce that in 2019 two of our members, Alessio Figalli and Tudor Ratiu, were elected to the Academia Europaea. The object of Academia Europaea is the advancement and propagation of excellence in scholarship anywhere in the world for the public benefit and for the advancement of the education of the public of all ages.

Alessio Figalli

2019 awards and distinctions

Congratulations to our member Alessio Figalli (ETH Zürich) for his different 2019 prizes, awards and distinctions:
Doctor Honoris Causa Award; Foreign Member of the Academy of Sciences of Bologna; Gili Agostinelli Prize of the "Accademia delle Scienzedi Torino", Knight of the Order of Merit of the Italian Republic.

Renato Renner

AHP Prize

Congratulations to Marius Junge, Renato Renner, David Sutter, Mark M. Wilde, and Andreas Winter, who were awarded the AHP Prize for the paper: Universal Recovery Maps and Approximate Sufficiency of Quantum Relative Entropy. Each year a prize founded by Birkhäuser is awarded for the most remarkable paper published in the journal Annales Henri Poincaré.

Corinna Ulcigrai

2020 Brin Prize for Dynamical Systems

Congratulations to our member Corinna Ulcigrai (UZH) who is the recipient of the 2020 Brin Prize for Dynamical Systems for her fundamental work on the ergodic theory of locally Hamiltonian flows on surfaces, of translation flows on periodic surfaces and wind-tree models, and her seminal work on higher genus generalizations of Markov and Lagrange spectra.

Maryna Viazovska

2020 European Mathematical Society Prize & 2019 Fermat Prize

Congratulations to our member Maryna Viazovska (EPFL) who was amongst the 10 outstanding young researchers who received the 2020 EMS prize. The EMS Prizes are awarded every four years in recognition of excellent contributions in mathematics. Maryna Viazovska also won the 2019 Fermat Prize for research in Mathematics for her solution to the famous sphere packing problems in dimensions 8 and 24.

Wendelin Werner

Elected to the Royal Society

The renowned Royal Society has elected Wendelin Werner as its member. The ETH mathematician now officially belongs to the "Foreign Members of the Royal Society (ForMemRS)". The traditional British learned society has existed since 1660 and only admits scientists as its members who have made an "outstanding contribution to scientific understanding and its use for the benefit of humanity".

Alice Gasparini

2020 CPEP Award

Congratulations to Alice Gasparini (UniGE) for receiving the 2020 CPEP Award for: Excellence in Teaching Contemporary Physics. Since 2008 Dr. Gasparini has been teaching mathematics and physics at Geneva secondary school in Switzerland, and is a scientific collaborator at the University of Geneva. She has developed activities, a course, and a book on the subjects of general relativity and cosmology, exclusively based on high school mathematics and physics.

Qingtao Chen

ICCM Best Paper Award

Congratulations to our alumnus Qingtao Chen (ETH Zurich, Felder Group), for winning the Best Paper Award at the International Consortium of Chinese Mathematicians (ICCM). His paper was entitled "Volume conjectures for the reshetikhin–turaev and the turaev–viro invariants". Qingtao Chen is now Assistant Professor at the New York University Abu Dhabi.

Avelio Sepulveda

2019 Francisco Aranda-Ordaz Prize

Congratulations to our Alumnus Avelio Sepulveda (ETH Zurich, W. Werner Group) who received the 2019 Francisco Aranda-Ordaz Prize for his PhD research: "Exit sets of the continuum Gaussian free field in two dimensions and related questions". This prize is awarded by SLAPEM and co-sponsored by the Bernoulli Society. It is awarded every 2-3 years to one PhD in Probability and one PhD in Statistics, written by students from Latin America regardless of the country of the university offering the degree.

Grants


Shaula Fiorelli and Pierre-Alain Cherix

SNSF Agora Grant

Congratulations to our members who received the SNSF Agora Grant which encourages researchers to communicate to the general public. Their project, *Leonardo in Perspective*, was an exhibition to mark the 500th anniversary of Leonardo Da Vinci's death.

Alessandro Sfondrini

SNSF "Spark" Grant

Congratulations to our member Alessandro Sfondrini (ETH Zurich - Gaberdiel Group) and Burkhard Eden (ETH Zurich) for receiving the SNSF Spark Grant for their project: Exact correlation functions in AdS/CFT.

Vincent Tassion

ERC Starting Grant

Our member Vincent Tassion was awarded an ERC Starting Grant for his project Critical and supercritical percolation. Vincent is focusing on the mathematical study of models arising in statistical mechanics. These models describe different mechanisms that give rise to phase transitions in physics. Such models include percolation processes, which are the main topic of his ERC project. A number of groundbreaking results have improved the understanding of percolation. As some fundamental questions remain unanswered, Vincent aims to answer some of them by establishing new connections between percolation theory and other fields of mathematics or theoretical computer science.

New Members

Juhan Aru

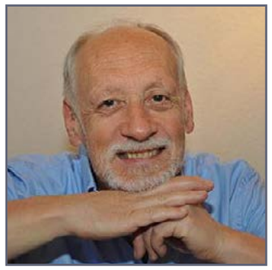
EPFL

We welcome Juhan Aru will be joining our Statistical Mechanics research project. He was previously a SwissMAP postdoc member in Wendelin Werner's group (ETH Zurich). His research interests include how to mathematically describe and study systems where geometric structure and randomness interact. The mathematical field studying such phenomena lies at the interface of probability theory, analysis and mathematical physics. He works on random curves (SLE curves), height functions (Gaussian free field) and other random geometric structures (e.g. Gaussian multiplicative chaos), often with roots in the phenomena of statistical physics.

Artur Avila

University of Zurich

Artur Avila is a professor at the Institute of Mathematics of the University of Zurich. He will be joining our Statistical Mechanics research project. His main research interests lie primarily in dynamical systems and spectral theory. He is one of the winners of the 2014 Fields Medal, being the first Latin American to win such an award. Avila is known for proving the "conjecture of the ten martinis" along with mathematician Svetlana Jitomirskaya. He also proved the Zorich–Kontsevich conjecture together with Marcelo Viana.



Nicolas Gisin

University of Geneva

We would like to welcome Nicolas Gisin as a new SwissMAP member. He will be joining our Quantum Systems research project. His research interests lie in: quantum physics - from foundation to application in quantum information science, quantum communication, open quantum systems, indeterminism and non-locality.

Nicolas Brunner

University of Geneva

We would like to welcome Nicolas Brunner as a new SwissMAP member. He will be joining our Quantum Systems research project. Nicolas is an associate professor in the group of applied physics at the University of Geneva. His research interests are quantum information theory, foundations of quantum mechanics and quantum thermodynamics.

Mikaela Iacobelli

ETH Zurich

We would like to welcome Mikaela Iacobelli as a new SwissMAP member. She will be joining our Statistical Mechanics research project. Mikaela is a professor at the Department of Mathematics at ETH Zürich. Her research is focused on the study of problems arising from the wide context of statistical mechanics. More precisely, she is interested in the analysis of partial differential equations in kinetic theory. Part of her work concerns the analysis of singular limits for Vlasov-type equations. She makes extensive use of PDEs techniques, optimal transport, probability, calculus of variations, and Riemannian geometry.

Chiara Saffirio

University of Basel

We welcome Chiara Saffirio as a new SwissMAP member. She will be joining our Quantum Systems research project. Her research focuses mainly on the rigorous derivation of effective evolution equations from the dynamics of many-body classical and quantum systems, with special emphasis on the Boltzmann equation. The tools she uses come mostly from kinetic theory, functional analysis, semiclassical analysis, statistical mechanics and probability.

Renato Renner

ETH Zurich

We would like to welcome Renato Renner as a new SwissMAP member. He will be joining our Quantum Systems research project. Renato is a Professor for Theoretical Physics and head of the research group for Quantum Information Theory at the ETH Zurich. His research interests are in the area of quantum information science, quantum thermodynamics, and the foundations of quantum physics.

Alexander Zhiboedov

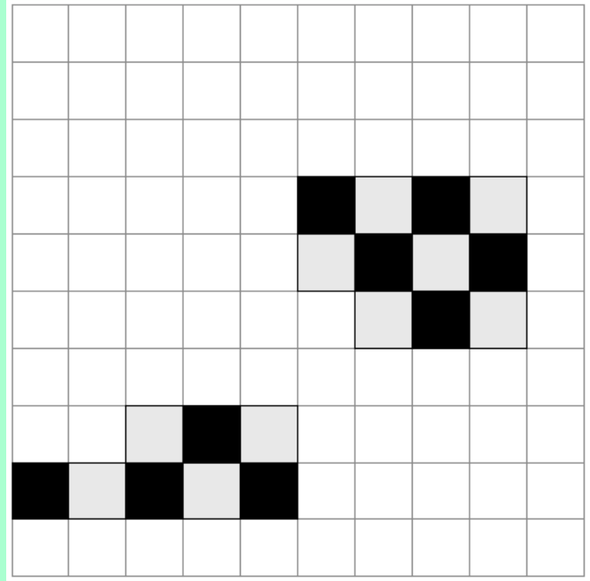
CERN

We welcome Alexander Zhiboedov who will be joining our Field Theory and String Theory research projects. Alexander is interested in understanding the space of quantum field theories (QFTs), especially the strongly coupled models. He applies and develops nonperturbative methods of the conformal and S-matrix bootstrap which rely on general principles, such as symmetry and quantum mechanics. One motivation for this work is holography which relates QFTs to quantum gravity in spacetimes with one extra dimension. By understanding the space of consistent QFTs via bootstrap methods one hopes to understand nonperturbative aspects of quantum gravity and string theory, which are hard to

Puzzle Corner

1. Infected Grid

Initially, 9 of the 100 squares in a 10 x 10 grid are infected. At a given instant, a square becomes infected if at least two of its neighbors (sharing a side) already are. Can the infection spread across the entire grid?



2. The Strawberry Tart

Luke: How old are your 3 children?
Eva: The product of their ages equals 36
Luke: I need more information
Eva: The sum of their ages is the house number you can see on the other side of the street
Luke: I'm sorry, but in hindsight I still can't determine the age of your kids yet
Eva: The oldest one loves strawberry tarts
Luke: Ah, now it's clear! I know how old your children are

Can you determine the ages of the 3 children?

3. Problem in the dark

You enter a room. On a table there are some counters, each of which has a red side and a blue side. Twenty of these counters have their blue side facing up while the others have red facing up.

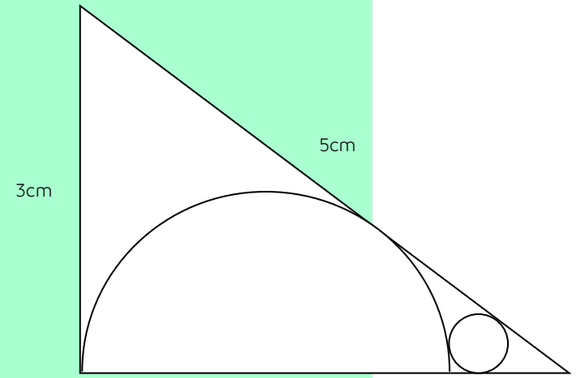
Your task is to separate the counters into two piles, not necessarily of the same size, but so that each pile contains exactly the same number of counters with blue side up. To do this, you can turn over as many counters as you like.

Here's the catch: the room is in total darkness.

How would you separate the counters into two piles so that each pile contains the same number of counters with blue side up?

4. The Circle inside the Triangle

Can you caluclate the area of the small circle inside this triangle?



5. Without Head nor Tail

On a distant island, a valiant knight must face dragons with several heads and tails. With a sword, the knight can cut off either: one head, two heads, one tail or two tails.

But these dragons have magical powers: cut off one head, and he will instantly regrow another one; cut off one tail, and he will regrow back two! On the other hand, if you cut off two heads with a single sword strike, nothing grows back... but two tails cut off at once are replaced by a new head. Of course, a dragon is only completely dead when it has no head or tail left.

How do you kill a magical dragon with 5 heads and 7 tails?
Are there any immortal dragons? Which ones?

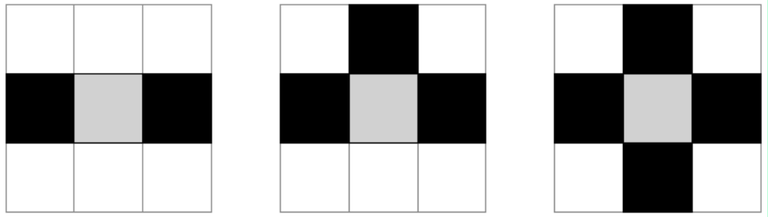
6. Positive integers

Does there exist a set M of positive integers with the following property: each positive integer outside of M is the average of two dierent elements of M, while no positive integer in M has this property?

Answers

1. Infected Grid

No. The total perimeter of the infected region never increases.



Initially, it is at most 36, so it cannot reach 40.

2. The Strawberry Tart

The children are 2, 2 and 9 years old respectively.
Eva's first answer, allows you to find 8 possibilities (hence Luke's need for more information).
1-1-36 1-2-18 1-3-12 1-4-9 1-6-6 2-2-9 2-3-6 3-3-4

Luke's second request for information ("I'm sorry, but..."), indicates that at least two of the possibilities have the same sum.
1+6+6=13 2+2+9=13

Since both possibilities indicate that two of the children are twins, Eva's last clue ("The oldest one loves strawberry tarts") allows you to find the right answer: where the oldest child is not one of the twins.

3. Problem in the dark

Divide the counters into two piles: one consisting of a randomly selected 20 counters and the other containing the rest. Now turn over each counter in the pile of 20.

Suppose that the pile of 20 contains n blue counters. Then, since there are 20 blue counters in total, the other pile has 20 - n blue counters. Since the pile of 20 has n blue counters, it must have 20 - n red ones. By turning each counter over, we are left with a pile having n red counters and 20 - n blue ones - exactly the same number of blues as in the other pile.

Puzzle contributors:
No 3: Mathscope & RTSdécouverte | Monthly maths problem | https://scienscope.unige.ch/mathscope/
No 1, 6: ETH Math Youth Academy | https://people.math.ethz.ch/~kslavov/
No 2, 4, 5: Alice Gasparini | University of Geneva

4. The Circle inside the Triangle

We name $a = 4\text{cm}$, $b = 3\text{cm}$, $c = 5\text{cm}$ and α, β, γ are the angles opposites respectively to a, b and c. Moreover, $x = a - 2R$, where R is the radius of the big circle, r is the radius of the small cercle and θ is the angle between side a and the line connecting the centres of the two cercles.

$$\frac{R}{b} = \tan\left(\frac{\alpha}{2}\right) = \frac{1-\cos(\alpha)}{\sin(\alpha)} = \frac{1-b/c}{a/c} \quad (1)$$
$$\Rightarrow \quad \frac{R}{3} = \frac{1-\cos(\alpha)}{\sin(\alpha)} = \frac{1}{2} \quad \Rightarrow \quad R = \frac{3}{2} = 1,5\text{cm}$$

$$\frac{r}{x} = \tan\left(\frac{b}{2}\right) = \frac{1-\cos(b)}{\sin(b)} = \frac{1-a/c}{b/c} = \frac{1}{5}\cdot\frac{5}{3} = \frac{1}{3} \quad (2)$$
$$\Rightarrow \quad x = 3r$$

$$\frac{r}{R+r} = \sin(\theta) \quad \text{and} \quad \frac{a-R-x}{R+r} = \cos(\theta)$$
$$\Rightarrow \quad \frac{r^2}{(R+r)^2} + \frac{(a-R-x)^2}{(R+r)^2} = 1$$
$$\Rightarrow \quad r^2 + a^2 + R^2 + 9r^2 - 2aR - 6aR + 6rR = R^2 + r^2 + 2rR$$
$$\Rightarrow \quad 9r^2 + r(4R - 6a) + a^2 - 2aR = 0$$
$$\Rightarrow \quad 9r^2 - 18r + 4 = 0$$
$$\Rightarrow \quad r_\pm = 1 \pm \sqrt{\frac{5}{9}}$$

The solution is $r = r_- = 1 - \sqrt{5/9} = 0,255\text{cm}$, and the surface of the little cercle is $A = \pi r^2 = 0,204\text{cm}^2$.

5. Without Head nor Tail

To kill a dragon with 5 heads (H) and 7 tails (T):
1. Cut off 2 x 2H and 3 x 2T (two at a time). You are left with 4H and 1T
2. Cut off 3 x 1T (one T at a time). You are left with 4H and 4T
3. Cut off 2 x 2T (two T at a time). You are left with 6H
4. Cut off 3 x 2H (two H at a time). You have defeated the dragon!

Immortal dragons are those with an odd number of heads and no tail. If you have tails you can always cut them off and make heads to get an even number of heads.

6. Positive integers

Yes. Let M be the set of positive integers whose expansion in base 3 contains only 0's and 1's. If x \in N–M, then 2x (just as any positive integer) can be writen as the sum of two elements of M; use that 2=1+1, 1=1+0, and 0=0+0. If x \in M, then 2x consists of only 0's and 2's, so it cannot be written as the sum of two distinct elements of M (there can be no carry operations).

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