SwissMAP
The Mathematics of Physics
National Centre of Competence in Research

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Fields Medal for two SwissMAP members: Hugo Duminil-Copin & Maryna Viazovska

The Fields Medal is the most prestigious award for mathematicians. It is awarded every four years at the International Congress of Mathematicians to two to four researchers under the age of 40 for their existing work and for the promise of future achievement.

The four laureates were announced during the 2022 IMU Award Ceremony in Helsinki. We congratulate our members Hugo Duminil-Copin (UNIGE) and Maryna Viazovska (EPFL) who earned the highest recognition in mathematics for their outstanding contributions to the field. Hugo has been recognised for the exceptional quality of his work in statistical physics and Maryna for her solution to the centuries-old problem of sphere-packing in dimensions 8 and 24.

Their impressive careers have captivated the attention of the scientific community for some time now. Listed amongst the currently most brilliant mathematicians, they are both recipients of numerous prestigious international awards and distinctions. Amongst them, Hugo was recipient of the 2017 Breakthrough Foundation's New Horizons in Mathematics Award and Maryna of the 2020 Latsis prize.

Hugo Duminil-Copin & Maryna Viazovska. Credit: UNIGE

Outstanding scientists

Hugo completed his PhD at the University of Geneva in 2011 and was promoted three years later to professor at the age of 29, "becoming one of the youngest researchers to be promoted to professor in the history of the University of Geneva."[1] Since 2016 Hugo splits his time between the UNIGE's Faculty of Science and the Institut des Hautes Etudes Scientifiques (IHES).

Maryna obtained her doctoral degree in Max Planck Institute of Bonn in 2013, followed by postdoctoral positions at the IHES and the Humboldt-Universität Berlin. She joined EPFL as a tenure-track assistant professor in 2017 and was appointed full professor in 2018. Today, Maryna became the second woman to receive the Fields Medal.

« I hope that the prize will help to inspire young girls to go into mathematics »
Latsis Prize Acceptance Remarks from Maryna Viazovska.[2]

A passion for physics and probability theory

« Hugo's work focuses on the mathematical branch of statistical physics. He studies phase transitions – sudden changes in the properties of matter, such as the transition of water from the gaseous to the liquid state – using probability theory. In particular, he uses probability theory to analyse mathematical models that describe three distinct phenomena: material porosity (via percolation theory), ferromagnetism (via the Ising model) and polymers (via the study of self-avoiding walks).

The first seeks to understand the mechanisms at work in porous materials such as pumice or coffee: what path does water take when it passes through such a material, for example? The second attempts to determine the behaviour of magnets, and in particular the progressive loss of their magnetism, when they are subjected to high temperatures. The third seeks to determine the positioning of polymers when they are immersed in a solvent.

By using new connections between these classical models, and by developing a theory of 'dependent percolation', Hugo Duminil-Copin has obtained transformative results that have improved our understanding of critical phenomena in statistical physics. 'This is purely fundamental research with no direct application. Nevertheless, modelling phase transitions mathematically is very important: it allows us to better understand the behaviour of matter. It gives us solid foundations that can be used for applied research with a view to industrial developments that are still impossible to foresee. » Hugo explained.[3]

Ground-breaking progress on long-standing sphere-packing problem

« The mathematical derivation of the densest possible arrangement of spheres in a given space goes back to a problem posed by the explorer Sir Walter Raleigh in the 16th century. He raised the question of how cannonballs should be stacked in the densest possible way on a ship. For centuries, luminaries of mathematics made assumptions about the sphere-packing problem in multidimensional space, which could only be proven three-dimensionally in 1998 through huge computer calculations.

Maryna caused a sensation in the world of modern mathematics with her original and amazingly simple calculation of the densest sphere packing in the much more complex

1 UNIGE CAMPUS Magazine No. 143 December 2020

2 EPFL News: Maryna Viazovska wins the 2020 National Latsis Prize

3 UNIGE Press Release : Fields Medal awarded to UNIGE Mathematician

Hugo Duminil-Copin. Credit: UNIGE - © Fabien Scotti

Maryna Viazovska. Credit: ©EPFL - Fred Merz

8th and 24th dimensions – the latter in cooperation with a research group.

The way spheres are packed in these particular dimensions is remarkably symmetrical, and uses the E8 and Leech lattices, respectively. »[4]

« The result in eight dimensions had been suggested by earlier work of Henry Cohn and Noam Elkies, who had conjectured the existence of a certain special function that would force the optimality of the E8 lattice. Maryna's construction of the function involved the introduction of unexpected new techniques and establishes important connections with number theory and analysis.

She subsequently adapted her method in collaboration with Cohn, Kumar, Miller and Radchenko to prove that the Leech lattice is similarly optimal in twenty-four dimensions. »[5]

« Research results on sphere packing in high-dimensional spaces also have practical applications in everyday technology. For example, in the analysis of crystal structures or in troubleshooting signal transmission of mobile phones, space probes or internet connections. While work on these two dimensions had previously been based on hypotheses, Maryna Viazovska's exploit delivered the mathematical proof and is already being used in efforts to solve fundamental problems in applied mathematics. »[6]

4 EPFL News: Maryna Viazovska wins the 2020 National Latsis Prize

5 CMI website

6 EPFL News: Maryna Viazovska wins the 2020 National Latsis Prize

SwissMAP

Both Hugo and Maryna have been part of SwissMAP since the first phase of the project. Hugo joined our Statistical Mechanics project led by Stanislav Smirnov (UNIGE) at the very beginning of the program in 2014. Former master student to Wendelin Werner (ETH Zurich), former PhD student of Stanislav Smirnov (UNIGE) and a close collaborator of Ioan Manolescu (UniFR) and Vincent Tassion (ETH Zurich), Hugo has greatly contributed in our mission to promote collaborative research.

Hugo is honoured and extremely proud to receive this Fieds Medal. "I want to share it with all my colleagues because mathematics is above all a collaborative process."[7]

Their impressive careers have captivated the attention of the scientific community for some time now. Listed amongst the currently most brilliant mathematicians, they are both recipients of numerous prestigious international awards and distinctions.

Furthermore, Hugo is also involved in the SwissMAP area of education and outreach. One recent example is the public talk he gave during the 2021 Colloque Wright: Does randomness really exist?

Upon her arrival at EPFL in 2017, Maryna joined SwissMAP as part of the Geometry, Topology and Physics project led by Rahul Pandharipande (ETH Zurich). Maryna has been colloquium speaker at the SwissMAP Annual General Meeting and contributed to our SwissMAP Perspectives Journal.

Furthermore, open questions regarding asymptotic sphere packing density will be one important collaborative research topic of SwissMAP's third phase, led by Maryna's group.

Six Fields Medalists

Hugo and Maryna's recognition brings the number of Fields Medalists within the SwissMAP consortium to six: Hugo Duminil-Copin (UNIGE) & Maryna Viazovska (EPFL) 2022; Alessio Figalli (ETH Zurich) 2018; Artur Avila (UZH) 2014; Stanislav Smirnov (UNIGE) 2010; Wendelin Werner (ETH Zurich) 2006. These prizes further reinforce the excellence of SwissMAP's research.

We rejoice with Hugo and Maryna and look forward to their undoubtably many further contributions to mathematics.

7 UNIGE Press Release: Fields Medal awarded to UNIGE Mathematician

Credit: UNIGE

Article by Mayra Lirot
NCCR SwissMAP

SRS
SwissMAP Research Station in Les Diablerets

A challenging first year of existence

The SRS did not have the easiest of starts due to the pandemic: its very first event, the 2021 Winter School in Mathematical Physics, had to be held online with only 5 people present in Les Diablerets to record the talks. Navigating through the everchanging health restrictions proved quite challenging, but very few events got rescheduled.

It was however a relief to be able to hold the SRS Inauguration Ceremony in person on September 13, 2021. Speeches by local representatives as well as UNIGE and ETH Zurich representatives were followed by public talks by Alessio Figalli (ETH Zurich) and Nicolas Gisin (UNIGE). Everyone later shared an apero in the Hotel Les Sources backyard.

All our thanks to Patrick Grobéty (bottom left) for his trust and cooperation!

SRS Scientific Council

New Scientific Council member:

Denis Bernard's research activities lie at the interface between mathematics and theoretical physics, covering different areas of mathematical physics, including random geometry, conformal field theory, integrable systems and their applications, or turbulent systems and turbulent transports, as well as out-of-equilibrium quantum systems.

SRS Scientific Council members

- Pr. Denis Bernard, CNRS & LPENS
- Pr. Giovanni Felder, ETHZ
- Pr. Matthias Gaberdiel, ETHZ
- Pr. Marcos Beiras Mariño, UNIGE
- Nuriya Nurgalieva, ETHZ
- Claudia Rella, UNIGE
- Pr. Stanislav Smirnov, UNIGE
- Pr. Chenchang Zhu, Göttingen University

Tribute to former Scientific Council member

Krzysztof Gawędzki, emeritus CNRS research director at the École Normale Supérieure (ENS) in Lyon and member of the SRS Scientific Council, died on Friday, January 21, 2022, at the age of 74. His broad knowledge in mathematical physics conferred him a leading role in the domain.

SRS Team

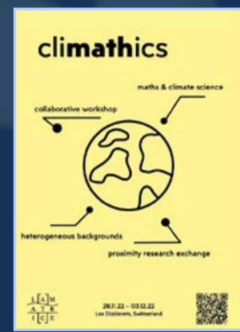

Anton Alekseev (UNIGE), Co-Director | Renato Renner (ETHZ), Co-Director | Elise Raphael (UNIGE), Science Officer | Séverine Gros (UNIGE), Events Officer

In January 2022, Séverine Gros (far right) joined the SRS team as events officer. Séverine has a background in art history and art market. She is one behind the new SRS Instagram account and video editing, amongst many other things!

What's next?

2022
This year's outreach event is the Let's talk about outreach! conference in October, which will bring together different actors of mathematics popularization and culminate in a exciting mathematics fair open to the general public.

The SRS strongly encourages interdisciplinary events, some of which are externally funded or partially supported by SwissMAP, such as the November Climathics conference.



2023
From recurrent schools and workshops (Winter School in mathematical physics, HAGS, Workshop in Statistical Mechanics) to large international events part of Simons Collaborations (S-matrix Bootstrap Workshop, Categorical Symmetries in QFT School & Workshop), the 2023 SRS program is exciting and reflects the diversity of SwissMAP's research interests.

Call for proposals 2024
The call for proposals 2024 is in progress and will end on September 30^{th}. Thanks to the additional funding received by SwissMAP in its third phase, more events than originally planned will be considered.

https://swissmaprs.ch/

Recordings from several previous conferences are available online.

Subscribe to the SRS mailing list to stay up to date with the yearly call for proposals & events program.

A conversation with Peter Hintz

Born in Kassel, Germany, Peter received a PhD in 2015 from Stanford University under the supervision of András Vasy. He was a Research Fellow (2015-2017) at UC Berkeley and was appointed as a Clay Research Fellow at the CMI. He is a professor at the Department of Mathematics at the ETH Zurich.

Peter Hintz studies partial differential equations, general relativity and microlocal analysis. His current research focuses on stability problems for solutions of Einstein's field equations. He is joining the SwissMAP Field Theory & Geometry, Topology and Physics projects.

When and how did you get interested in mathematics, mathematical physics and physics?

It started when I was quite young. My earliest math-related memory is from a book about inventions of mankind. One of the inventions was algebra with a short column on how to solve linear equations, or systems of two linear equations with two unknowns. I must have been only 6 years old, but I remember spending days trying to solve equations and having the greatest fun. In middle school, I was drawn into participating at Math Olympiads, but I was not very successful, nor did I enjoy it much. I then did an internship at the local University of Kassel and there was a professor there, Werner Varnhorn, who was a big influence on me. I attended his lectures though I didn't understand much. These were undergraduate classes in calculus, and my first encounter with serious mathematics.

But when I started studying in Göttingen, I guess I was tarnished from my unpleasant experience of Math Olympiads so, I went into physics and computer science (CS) instead. But clearly, I couldn't shake off my interest in math. In my second semester, I had to take an electromagnetism class. There was a lot of math involved in the form of partial differential equations, and I wanted to know more. It so happened that at the time there was a professor, Ingo Witt, in the math department who was going to teach a 4-semester series on partial differential equations. I loved the class and I suppose this put me on the trajectory I have been on ever since.

Since I didn't like the CS undergraduate, I dropped it and replaced it with math. In physics, I was consistently drawn towards the theoretical and mathematical parts of my studies. I ended up doing a double major in physics and math. My undergraduate friends would laugh at me, because in the 1st semester, I said I'd never become a mathematician. And it took two semesters for me to change my mind.

Why did you choose the academic path?

One of my main hobbies for over 25 years has been playing the violin, and I seriously considered following a career in music. But I was afraid that my curiosity in science would not be sufficiently catered to.

I ended up choosing science, but I let things happen as they come. When I started my undergraduate, I didn't plan to become a professor. First you need to see how good of a student you are. Since I was a successful student, I decided I could do a PhD in math. And when my PhD was successful, I decided to try for a postdoc. Once I was close to the postdoc stage, it became clear to me that I would really go for it. My parents had told me that it was clear to them, even before I went to college, that I would be a professor. But for me, I just let it happen.

Did it change at some point or was it always very clear for you?

At the early stages of a PhD, you're still learning what's out there and trying to achieve something. I remember one low moment when I was considering taking a lot of CS and coding classes at Stanford. I wanted to have a skill set enabling me to get a sensible job, should I decid not to stay in math. But then a few weeks later, I managed to prove something, and I forgot all about it.

Another thing continues to nag me on occasion. My brother is a doctor, my sister a social worker, and both my parents are retired high-school teachers. From my perspective, what they do is useful and has an immediate benefit to society. It is much more immediate than what I do. When I teach representation theory to students, it does not have an immediate effect on their well-being. Quite the contrary, I fear. Occasionally, I struggle with what the greater benefits come from being an academic. Of course, scholarly endeavours are of value, and I have these mild doubts only when I'm really stuck on a problem. Once I get unstuck, I'm all for it again. And perhaps, a little self-doubt is not such a bad thing. It helps me to remind myself why I'm doing this.

Which research topics got you into academia in the first place?

One of the main topics, as I mentioned previously, was electromagnetism. And by the time I had finished my undergraduate, I was interested in partial differential equations and differential geometry. In Stanford, at the time, there were very famous people in those fields, and I briefly considered working in differential geometry. But I met my thesis advisor, András Vasy, who was working on wave equations on spacetimes in relativity. I liked the research he was doing and decided to go that route instead. He used a toolkit called microlocal analysis in his research.

It was a great coincidence that I had already studied this toolkit during my undergraduate in Göttingen. It is not commonly taught in many universities, but my professor, Ingo Witt, was a big fan of it. At Stanford, András used this state-of-the-art math toolkit to work on physics-related problems. There are still many exciting things to do in this field, and the trajectory my advisor put me on is still the one I am on today. So, he was definitely my biggest influence.

What are you working on right now?

The main problems are black holes and the energy decay of waves over time. The main challenge I'm working on right now concerns black hole stability. The talk I gave at last year's SwissMAP Annual General Meeting was about it.

When you picture a black hole, you would probably see an image of a black sphere with things falling into it, and the black hole eats everything around it. But the simplest sort of black hole is much more benign. The sphere is sitting there, it has an event horizon, and when you cross it, you cannot come back out. The gravitational attraction is too big. But there is nothing outside of it, just vacuum everywhere. So, it is a time-independent situation, and the black hole is simply there, not doing anything.

But real black holes out in the universe are of course not like that. There is some matter around, or some form of energy, like gravitational waves coming in. The question of the black hole stability problem consists of understanding how a black hole reacts to these small inputs. If a little energy arrives in the vicinity of the black hole, some might be absorbed by it, and it might gain some mass or start spinning slightly. Many of these incoming waves might, however, instead get scattered away again. That is something you could measure as gravitational waves, here on Earth.

The conjecture is that this black hole should settle down again to a boring state. If you wait long enough, then all the gravitational waves floating around the black hole will ultimately dissipate by either flowing away, or into the black hole. And in the end, there is nothing left anymore, except a black hole that is once again doing nothing, and a vacuum around.

OOne can regard this as a mathematical investigation into whether the idealized black hole solutions are sensible approximations of real black holes in the universe. If some of these idealized black holes upon the slightest perturbation become something totally different, then they're probably not out there in this form. In any case, the conjecture is that they are stable and sensible physical objects.

So, this is a problem I'm trying to solve. But along the way, I try to develop some interesting mathematical methods to attack this problem that are in the realm of micro-local analysis. This is a math toolkit for understanding, for instance, the propagation of waves. Which way do they go; how do they behave in time and so on. It's a very powerful tool for tracking position and momentum of little wave packets. This is the pure math side of what I'm doing, and the black hole part is a nice application of it. I have been working on this problem for about 6 years now.

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

Currently, various groups are zeroing in on proving this conjecture. But in math 99% proof is equal to 0% proof. Only once you have everything done can you declare victory. Nobody has it yet, but it seems like it will be resolved soon, in a year or two. [Note added after the interview: an arXiv preprint appeared in late May claiming a proof of the conjecture.]

In relativity, there are still many other problems to look at. Many of them relate to black holes. For instance, many researchers study the structure of the interior of black holes and there's something called the strong cosmic censorship conjecture by Roger Penrose who got the Nobel prize in physics in 2020. The question is about whether deep inside a black hole, there is always a terminal singularity. If you get too close to the black hole, you and your spaceship get ripped apart, and even space-time ceases to exist in the standard sense.

The conjecture is that this is what will typically happen, and many people are working on this.

There is work being done in the field of anti-de Sitter space where the question is whether it is unstable. There is an expert on AdS who's moving to EPFL, Georgios Moschidis. He's working on AdS and its instability properties, and how one can focus gravitational waves to create some sort of singularity.

What I'm particularly curious about is understanding interactions between black holes rigorously. I predict this will be a major topic in the next 5-10 years. The gravitational wave measurements that have been done in the actual universe are always about a very intense event. Like a black hole merger or a merger with a neutron star for example. But mathematically, there's not a single description of this situation yet. The challenge is to rigorously understand what happens when two black holes collide. From a physics perspective, it is a very natural question, but it is very hard from a math perspective. I believe that slowly people are figuring out the tools required to study such questions, and I hope to work on it as well.

The math toolkit I use in my work has become a set of tools one can apply to many different problems, also outside the field of relativity. There is a lot of work being done in inverse problems right now, for example. This is where you study the interior of a body by taking measurements on the boundary. Imagine you have a rubber ball, and you measure the vibrations on the side when you hit it in a specific spot. You try to figure out the internal structure of the ball by measuring only the vibrations on the boundary. The hit is in a precise location, with precise momentum, so it is a very micro-local thing. You track this elastic wave and how it propagates through the medium, and how the properties of the medium influence the wave's propagation.

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

There are a few. My proudest moment was when András Vasy and I managed to prove the black hole stability problem in the first general case - of slowly rotating black holes inside of universes that undergo an accelerated expansion like our own. The proof concerns an idealised situation where the universe is expanding, there is only one black hole and it is rotating slightly, and the rest is almost entirely energy-free. Our universe is of course, far more interesting than that, but this is as far as math can go for now. We proved it in 2016, and it was a surprise to the GR community because the tools we were using, at the time were completely new, and some experts in the field did not think they would be effective for such problems. Then we proved them wrong, which was a small victory. It was exciting to come first in this problem that many people were working on.

I then got a Clay Research Fellowship, from the Clay Mathematics Institute. They sponsor math events and early career mathematicians. This is a very select group of people, as they typically only choose two per year, and many went on to be very successful. A fair number of recent Fields medallists were Clay Research fellows previously. This is a sort of early knighthood for mathematicians, and I was extremely proud to receive it.

Another high point was getting the assistant professorship at MIT. When I was 11 years old, I watched a documentary about an MIT robotics lab, and it became my dream to go to MIT. When I applied to grad school, I was put on the waitlist, and by the time I was accepted, I had already decided to go to Stanford; and then I ended up choosing Berkeley for my postdoc. When I ultimately got the tenure track professorship at MIT, it was a childhood dream come true. I loved working there, but was not able to see much of it, as the pandemic started shortly after. And then Alessio Figalli sent me an email asking whether I would like to apply to my current position. And when you get an email from Figalli, you know, you should follow up on it. So, I applied and was hired. I once told my parents that the only place I would ever consider coming back to Europe for was ETH Zurich, and that is exactly what happened. My wife and I had not planned to leave the US so soon, but my wife also found a position at ETH; so it really worked out perfectly for us.

What have been the greatest challenges you had to face?

This is a tough question to answer, as I consider myself extraordinarily lucky in my academic career. I suppose the challenges are more of a personal nature. I left Germany for my PhD at Stanford when I was 20 years old. All my previous studies were always close to home, and suddenly I went across the world and was all by myself. That was probably the most exciting time in my life, but during the first year, when I did not yet have a proper group of friends, I would get homesick. It was challenging, as you cannot just go home to recharge. You must make your own stand.

The single hardest thing happened last year though. After 10 years in the US, we had green cards, bought a house and made our life there. Then we had to pack everything up, sell the house and move to Europe. And all this with a 9-month-old baby, my wife pregnant with our second child, and during a pandemic. We both agree that was the single most challenging time in our lives, but luckily Switzerland was very welcoming, and the bureaucracy was easy-going. And we both have positions in the same place, so we consider ourselves to be very lucky.

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

I would say you need to work very hard because competition is extremely tough and there are few jobs available. When you feel you're close to solving a problem, work relentlessly until you have it. You need to have this drive to see things through, and when you're young, you have the most energy to do this.

It is also important to regularly attend seminars and conferences and talk to people. Listen to what they're working on, so you get a feel for what's going on out there. And tell them what you're doing so they know you exist. The solo experience where you just write papers and someone offers you a job does not work. You need people to write you recommendation letters, and people who will pay attention to your application. Without a network, it will be difficult to get hired. Of course, your advisor can help, but it is you trying to get the job, not your advisor.

Lastly, one should make use of one's advisor. The advisor is interested in making sure the student succeeds. And having more experience, the advisor has a clearer view of what problems are interesting to the community; what problems are doable and what problems are not currently worked on by many other groups. That is what the advisor is there for, and one should take advantage of that.

Finally, to learn some more about you, when you are not doing research how do you spend your time?

Do you have any personal hobbies outside of research?

My main hobby right now are my two sons at home. One is 17 months, and the other 3 months old. So most if my time outside of work is taken up by playing, cuddling, and signing.

I also play a lot of violin. I joined every university orchestra in every university I studied at and was usually the concertmaster. I always took it very seriously and practiced a lot. The pandemic put this on pause, but it is slowly returning now. I hope to get back into it more in the fall. There is an amateur orchestra in Zurich that I would like to join for rehearsals once a week, and weekend concerts.

Conversation with Peter Hintz
February 2022, Zurich/Online

Interviewed by Maria Kondratieva
On behalf of NCCR SwissMAP

A conversation with Vincent Vargas

Vincent Vargas obtained his PhD in probability and statistical physics at the University Pierre and Marie Curie under the supervision of Francis Comets. He was a research fellow at the CNRS and has been appointed associate professor at the Department of Mathematics at the University of Geneva as of 2021.

His research interests include probability, mathematical physics, statistical mechanics, quantum field theory. He is joining the SwissMAP Field Theory & Statistical Mechanics projects.

When and how did you get interested in mathematics, mathematical physics and physics?

I would say rather late. I really started getting interested in maths and mathematical physics when I discovered a theory called gaussian multiplicative chaos, which has numerous applications such as in turbulence and finance... and of course the thing I've been working on the past 6-7 years which is Liouville field theory. I'd say my interest started when I was about 25 years old.

Why did you choose the academic path?

I actually hesitated a long time before choosing an academic path. I really chose it when I started at the CNRS after my PhD thesis. Because I wanted to contribute to increasing the general knowledge in science and so I felt that at that point the academic path was more meaningful to me.

Have you ever worked outside academia?

Yes, after my PhD thesis and before CNRS, I had a 9-month window where I experienced working in a hedge fund. I worked in a hedge fund called Capital Fund Management, and I met very interesting people who were trying to apply ideas of statistical physics to stock markets. And that's where I met Jean-Phillippe Bouchaud and Marc Potters, who are very interesting scientists. And I was really impressed and happy working in this fund.

And then I received an offer from the CNRS, and I decided to work in academia. At that time, I had started to discover this theory of gaussian multiplicative chaos, and I felt that there were really lots of things to do around this theory, and lots of applications to develop. And I'm still actually working around this object. So, it is this passion for this tool of mathematical physics that made me choose academia.

Could you tell us about your experience working in the hedge fund?

I was working in volatility modelling, and it was interesting because I learnt what it was to try to solve a problem fast and efficiently. Working in this fund, I particularly learnt to work with people who have very different backgrounds. There were computer scientists, physicists, mathematicians and people from the business world. This was interesting because I was only used to working with people from academia. It was a fruitful experience to meet and understand other environments.

Which research topics got you into academia in the first place?

I really decided to work in academia when I started my PhD with Francis Comets, who was a great PhD advisor by the way. And he put me on a topic called directed polymers. It was an interesting topic and the first kind of profound research I did. At the end of my PhD, I switched to the gaussian multiplicated chaos theory. But what made me enter the field of statistical physics was the study of directed polymers. Which is a very hard topic by the way, with lots of open questions remaining.

What are you working on right now?

Right now, I'm working on 2d option field theories with exponential interactions. I am trying to define objects that are defined mathematically and appear a lot in physics. For example, in string theory, in the theory of random surfaces, you have these so-called quantum field theories that appear. And with my colleagues, we are trying to define all these quantum field theories that appear and to study them thoroughly using probabilistic tools.

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

I do want to emphasise that I'm quite amazed about how quickly young researchers have been developing conformal field theories recently. I'd say that young people are really developing exciting things. I'm currently working with a young postdoc who's in Berlin, Guillaume Baverez, on trying to understand the algebraic structure behind new Liouville field theory. With Rémi Rhodes, Antti Kupiainen and Colin Guillarmou, we have developed a probabilistic approach to this new Liouville conformal field theory. And now, Guillaume Baverez has joined us to understand more thoroughly the algebraic version of this theory.

I have a student, Baptiste Cerclé, who is doing impressive research right now. He's working on a generalisation of Liouville theory called Toda conformal field theory.

And let me mention, that I'm quite amazed by the recent work of Maurice Hang, Xiong Jin, who are establishing conformal bootstrap formulas in the framework of Sheffield and Werner's conformal loop ensembles. These conformal loop ensembles have a very strong geometric flavour and are linked to this Liouville theory that we defined with my colleagues. And they are adapting some of our techniques and brining their own ideas into the field to understand conformal loop ensembles.

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

There are several moments I really liked. First, over 7 years ago, when we understood that we can understand this Liouville theory, using probability. At the time it was controversial, there was a physics theory. But we understood that probability could define this theory properly.

We just finished a program recently, that shows that this probabilistic theory is equivalent to the bootstrap construction that uses physics. So, one of my favourite moments in my career was when my colleagues and I (Antti Kupiainen, Rémi Rhodes and Francois David) understood that the Liouville theory could be tackled through probability.

And recently, when we proved the equivalence with our probabilistic theory and what physicists are doing in Liouville which is called the conformal bootstrap.

What have been the greatest challenges you had to face?

One of the greatest challenges is also linked to the best moments of my career. When we discovered that we could really tackle Liouville theory using probability, I think in the beginning people doubted that we did the right thing. Many people didn't understand why we were doing this. People were sceptical about what we did and if it had anything interesting to say about what they were studying. And in the beginning, the biggest challenge was to convince people that we had defined the proper object, the real Liouville field theory. And that what we did, could indeed be interesting. Even for what they were working on. So, it took us a few years for our discovery to become popular.

Lots of physicists told us they thought one could not really make sense of Liouville theory, using probability. So, we had to prove and communicate, that what we were doing was not uninteresting.

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

I would advise them to try to quickly find a stable job, which will enable them to take risks in their research. Find an environment, where you're under reasonable pressure so you can develop your ideas. To do good research, it is important that you feel you have some time to develop your own ideas. That you're not just rushing to publish all the time, to keep on getting a job. I would advise them to take some risks.

I was very fortunate to have a permanent position in CNRS, so I had a stable situation. Which enabled me to take some risks, and in the end, it paid off.

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

First outside of research, I try to spend some time with my two daughters. I like to go to movies and restaurants. I try to do a bit of sport to compensate for all the restaurants I eat in. And I like to go swimming.

Conversation with Vincent Vargas
March 2022, Geneva/Online

Interviewed by Maria Kondratieva
On behalf of NCCR SwissMAP

The Cosmological Constant Problem

1 The Problem

Soon after Einstein had written his equations of General Relativity (GR) in 1915 [1], he applied them to find a cosmological solution, i.e., a solution which can describe the entire Universe on very large scales [2]. He assumed that on large scales the metric of the Universe should be homogeneous and isotropic and that it should be static. At that time the expansion of the Universe was not yet measured. He could only find a static solution by introducing a new term of the form $\Lambda g_{\mu\nu}$ to his equations, where Λ is a constant, the so called cosmological constant, and $g_{\mu\nu}$ is the metric of spacetime. He published his solution in 1916 and did actually not realize that it was unstable. The slightest (local) changes in the energy density lead exponentially fast away from the solution which makes it meaningless in any realistic situation.

On the other hand, Einstein also realized, that adding this 'cosmological term', which is of the order of $1/R^2$, where R is the size of his closed Universe, does not affect any of the successes of his equations in the solar system, most notably the perihelion advance of Mercury and light deflection around the sun. The curvature responsible for these effects is roughly R_S/r^3), where R_S is the Schwarzschild radius of the sun ($R_S \simeq$2km) and r is the distance sun-mercure for the perihelion advance and the radius of the sun for light deflection. Later it was shown that Einstein's equations including the cosmological term are the most general ones in four spacetime dimensions that are of second order in the derivatives of the metric and allow for a covariantly conserved 'left hand side' in Einstein's equations [3]. We need to require the latter since the energy-momentum tensor is covariantly conserved.

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = 8\pi G T_{\mu\nu}$$

In 1956, a year after Einstein's death, Gamov wrote [4] that Einstein had called the introduction of the cosmological term his "biggest blunder". Some science historians have doubted whether Einstein really ever used this expression (see [5] for a recent account on this story), but he certainly completely abandoned the cosmological term after the observation of cosmological expansion by Lemaître [6] and by Hubble [7].

In the presence of ordinary matter only, the expansion of the Universe is decelerated due to the global gravitational attraction. However, in 1998/99 three teams of observers [8, 9, 10] claimed to have measured that the Universe is presently undergoing accelerated expansion which is incompatible with a Universe dominated by normal matter with non-negative pressure but can be obtained with a cosmological constant. More precisely, the cosmological constant needed to fit present data on the expansion of the Universe is $\Lambda \simeq 2.3 \times (8\pi G\rho_0)$, where $\rho_0 = -T^0_0(t_0)$ is the mean matter density in the Universe today (we set the speed of light c = 1). In 2011 the first authors of these papers obtained the Nobel prize "for the disccovery of the accelerating expansion of the Universe through observations of distant supernovae".

"So what ?" the reader may think. Then Einsteinian gravity needs not only one constant, G, which is Newtons's constant of the gravitational force, but also a second constant Λ which is relevant only on very large, cosmological scales. Indeed, when expressed in the length scale used in cosmology 'Megaparsec' (1Mpc $\simeq$ 3.26 x 10^6 lightyears $\simeq$ 3.086 x 10^{24}cm), one obtains for the value best compatible with present data

$$\Lambda \simeq \frac{1}{(3000\text{Mpc})^2}$$

But the situation is not so simple. A term in the energy momentum tensor 'looking exactly' like the cosmological constant, namely $-\rho_v g_{\mu\nu}$ with a constant ρ_v appears also in quantum field theory (QFT). This is an energy momentum tensor with strongly negative pressure, $P_v = -\rho_v$. Actually, in QFT we cannot compute this term, it formally diverges (like several other quantities). However, since in quantum field theory only *energy differences* are physically meaningful and can be measured, we can safely 'renormalize' this divergence into a finite vacuum energy ρ_v. Differences of the vacuum energy from QFT have been measured in many experiments e.g. via the so called 'Casimir force': The vacuum energy between two perfectly conducting parallel plates is slightly larger than outside leading to a physical attraction of the plates. This has been measured in several beautiful experiments, see e.g. [11]. The presence of vacuum energy also leads to the well known 'Lamb shift' measured for the first time in 1947 [12], an energy shift in atomic spectra which cannot be obtained from the Dirac equation, but is explained by the effect of the atom on the vacuum energy which is slightly different in different atomic states. Lamb was awarded the Nobel Prize in Physics in 1955 for his discoveries related to the Lamb shift.

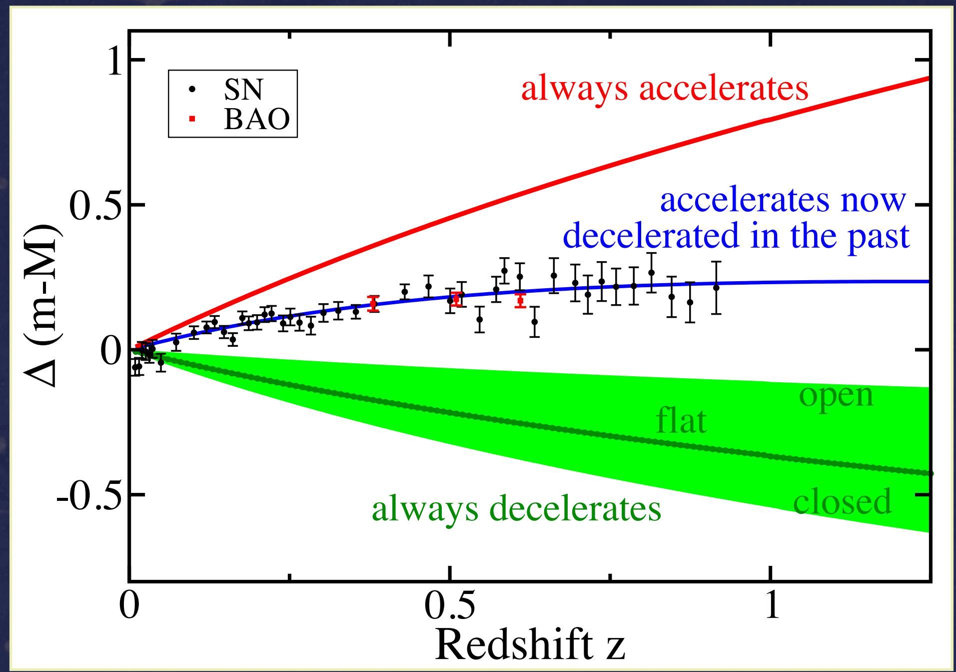


Figure 1: Binned data from 870 supernovae. The vertical axis is $\Delta(m-M) = 2.5\log(d_L/d_L^{\rm Milne})$. Here $d_L^{\rm Milne}$ is an empty Universe with negative curvature Ω_K=1. Figure from [14].

However, in Einstein's equation a constant vacuum energy does contribute. It gives rise to a cosmological constant of the value $\Lambda_v = 8\pi G\rho_v$. Actually, there is no physical experiment which can distinguish between Λ_v and Λ. Therefore, the fact that our theories obtain 'vacuum energy' from quantum field theory and 'a cosmological constant' in GR certainly is a manifestation that, so far, we did not manage to unify QFT and GR[1]. Since no experiment can distinguish between them, we should also not do so in our understanding. Vacuum energy and the cosmological constant are one and the same thing. The supernova measurements therefore tell us that the Universe is permeated by a vacuum energy density given by

$$\rho_v = \frac{\Lambda}{8\pi G} \simeq (0.7 \times 10^{-3}\text{eV})^4 ,$$

corresponding to an energy scale roughly of the order of the neutrino mass splittings[2].

Why should the constant vacuum energy have this value? What is more, when the theory undergoes a phase transition it changes its vacuum energy typically by an amount of the order of the energy scale of the transition. E.g. at the electroweak transition the energy density of the vacuum has changed by about $(100\text{GeV})^4$. If there is supersymmetry at say 10^4GeV or if there ever was a 'grand unified transition' at about 10^{16}GeV, we expect corresponding changes in the vacuum energy. How could they all add up to the highly fine tuned[3] value of 10^{-3}eV ? Such a small cosmological constant is also technically unnatural. This means, a small cosmological constant is not protected from quantum corrections by some symmetry principle, without very low energy supersymmetry[4], which contradicts experiments.

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1 However, the best present candidate that might unify GR and QFT, string theory, also does not solve the cosmological constant problem, unless one is willing to accept a landscape-based anthropic argument. I thank Julian Sonner for pointing this out to me.

2 The eV, 'electron Volt', is the energy an electron gains when traversing an electrical potential of 1 Volt. We set the speed of light c = 1. This means we measure masses in terms of energies via the formula E = mc² and, we measure times in terms of length scales which light can travel in the given time. We also set the Planck constant $\hbar = 1$, which means we measure length in terms of the Compton wavelength of the corresponding mass, $\lambda = \hbar/mc$, i.e., in inverse eV. Therefore an energy or mass density has the units $(\text{eV})^4$. Apart from eV we shall use the energy unit GeV = 10^9eV.

3 Writing the action of QFT and GR one finds that most constants that appear in the action have to be 'renormalized' and scale with the energy cutoff of the theory. Coupling constants and fermion masses only scale logarithmically while the Higgs mass scales quadratically, but the worst kid on the block is the cosmological constant which scales as the forth power of the cutoff energy.

4 In a supersymmetric theory, the contributions from bosons and fermions to the vacuum energy cancel each other and we expect ρ_v=0 for symmetry reasons.

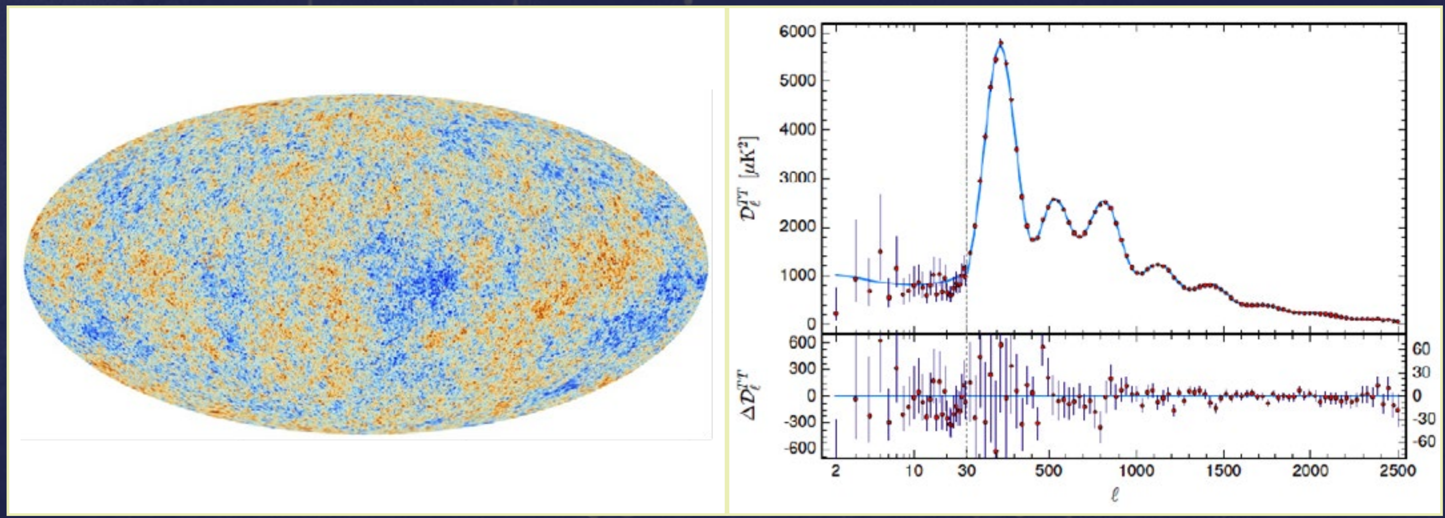

Figure 2: Left: The CMB sky as seen by the Planck satellite. An Aitoff projection of the sky is shown with the measured temperature fluctuations which have amplitudes around $|\Delta T/T| \sim 10^{-5}$.
Right: The angular power spectrum of the fluctuations in harmonic space. A harmonic ℓ corresponds to an angular scale of about π/ℓ. The peaks due to the acoustic oscillations of the baryon photon plasma are well visible with a first maximum at $\ell \simeq 200$ (On the left of the dashed vertical line the horizontal scale is logarithmic while on the right it is linear). Figures from [15].

On the other hand, a large vacuum energy of, e.g., $\rho_v \simeq (1000\mathrm{GeV})^4$, which might be protected by supersymmetry, corresponds to a curvature scale of the Universe of about $R \simeq M_{\rm pl}/\sqrt{\rho_v} \sim 0.02\mathrm{mm}$, in complete contradiction with the large flat Universe we observe. (Here $M_{\rm pl} \sim 2.4 \times 10^{18}\mathrm{GeV}$ is the reduced Planck mass.)

The first physicist who realized that the vacuum energy, if at all, must be very small was probably Wolfgang Pauli who said: "If we use the electron mass as the cutoff scale of quantum electrodynamics, the Universe would not even reach to the moon". By this he means to replace the infinite value of the vacuum energy by cutting the corresponding integral at an energy given by the electron mass. The author of [13] has redone this calculation, he finds a curvature radius of 31km for such a Universe.

Before cosmological acceleration was measured, many physicists (including the author of the present article) thought that the cosmological constant must be chosen to exactly cancel the vacuum energy so that we never measure a vacuum energy. But what if the vacuum energy changes e.g. during a phase transition? And also what about the measured accelerated expansion of the Universe? In the next section we discuss what cosmological observations have truly measured. We then discuss some attempts to solve this 'cosmological constant problem' before we conclude this essay.

2 What do cosmological data measure?

In cosmology there are several different distance measures that in a flat spacetime all result in the same answer. The so called 'luminosity distance', d_L, relates the flux F from a far away object with known intrinsic luminosity L to its distance via

$$F = \frac{L}{4\pi d_L^2}.$$

Objects with known intrinsic luminosity are so called 'standard candles'. Supernovae of Type Ia are (up to some modications) such objects and have been used to measure the luminosity distance. Apart from the distance one also measures the redshift z of the supernova. 1 + z is the factor by which wavelengths have been stretched, i.e., by which the Universe has expanded, since the light of the supernova was emitted. This leads to a relation $d_L(z)$ for each supernova. In a homogeneous and isotropic solution of Einstein's equations, a so called Friedmann-Lemaître (FL) Universe, this distance redshift relation can be computed in terms of the matter and energy content of the Universe. Assuming simply pressureless matter, spatial curvature and a cosmological constant one finds

$$d_L(z) = \frac{1+z}{H_0\sqrt{\Omega_K}} \sinh\left(\sqrt{\Omega_K}\int_0^z \frac{dz'}{\sqrt{\Omega_m(1+z')^3 + \Omega_K(1+z')^2 + \Omega_\Lambda}}\right)$$

Here H_0 the present expansion rate of the Universe, the so called Hubble parameter, $\Omega_K = -K/H_0^2$, where K is the (present) spatial curvature, $\Omega_\Lambda = \Lambda/(3H_0)^2$ and $\Omega_m = 8\pi G\rho_m/(3H_0)^2$, ρ_m is the present matter density of the Universe. Einstein's constraint equation requires that $\Omega_m + \Omega_K + \Omega_\Lambda = 1$. The above equation is valid for both, positive and negative curvature and also the limit $\Omega_K \to 0$ is well behaved. This expression for $d_L(z)$ has been fitted to supernova measurements, see Fig. 1.
A good fit to the data is obtained with $\Omega_K \simeq 0$, $\Omega_m \simeq 0.3$ and $\Omega_\Lambda \simeq 0.7$. Hence, at present, the expansion seems to be dominated by a cosmological constant. Such a model of the Universe is called the cosmological standard model and termed ΛCDM. Λ stands for the dominant cosmological constant and 'CDM' for cold dark matter which is dominating ρ_m. For reasons not discussed here, the bulk of the matter in the universe cannot be normal baryonic matter but must be some cold component which does not (or very weakly) interact with ordinary matter and photons, hence it is "dark". The dynamical Einstein equation which determines the acceleration of the scale factor a, is

$$\frac{\ddot a}{a} = -\frac{4\pi G}{3}\left(\rho_{\rm tot} + 3P_{\rm tot}\right).$$

Acceleration, ä>0 is only possible if the content of the Universe is dominated by a component with a strong negative pressure, $P<-\rho/3$, which is the case of vacuum energy. Hence the present energy momentum tensor of the Universe (including vacuum energy) violates the strong energy condition defined by $\rho+3P\geq 0$.

Distances in cosmology have also been measured by other means. The angular diameter distance d_A is defined as the distance which an object of known size L must have to be seen under a (small) angle α in the sky, $d_A=L/\alpha$. The angular diameter distance and the luminosity distance are related by $d_A(z) = (1+z)^{-2}d_L(z)$. In cosmology we do have a known physical distance, a so called 'standard ruler'. It is the distance a sound wave (called 'acoustic wave' in this context) of the baryon photon plasma has traveled since the big bang up to some redshift z, the sound horizon. In the Cosmic Microwave Background radiation (CMB) which was emitted at $z_{\rm CMB}\simeq 1080$, we see this ruler under an angle of about 1/2 degree. This allows a very precise measurement of the distance to the CMB, $d_A(z_{\rm CMB})$, see Fig. 2.

Similar acoustic oscillations are actually also seen in the fluctuations of the matter distribution and they have provided the three red points in Fig. 1. All these data are compatible with $\Omega_\Lambda \simeq 0.7$ with rather small combined error bars, more precisely, the minimal model with $\Omega_K = 0$ yields the constraints $\Omega_\Lambda = 0.689 \pm 0.0056$, which results in the vacuum energy of about $(10^{-3}\mathrm{eV})^4$.

This is a very brief resumé of the experimental situation which has many caveats and difficulties which are not explained here for the sake of brevity. Nevertheless, there are three very different observations from different times of our Universe which all yield the same result: The expansion history of the Universe is not compatible with matter and curvature only, but a component with a strong negative pressure, like a cosmological constant often more generically termed 'dark energy' (not to be confused with dark matter) must exist and actually dominate the present energy content of the Universe.

3 Solutions?

Is there a way out from interpreting this dark energy as a tiny vacuum energy? Might we have interpreted the data wrongly?

A first simple idea is the following: at intermediate to small scales the matter distribution of the Universe is not homogeneous and isotropic. In an FL model we solve for the metric of a homogenous and isotropic matter distribution. But Einstein's equations are non-linear, the metric of the homogeneous energy momentum tensor is not just the spatial average of the true underlying fluctuating metric. Small scale fluctuations in the energy momentum distribution might 'back-react' on the metric on large scales. This back-reaction idea seems very attractive, especially also since the cosmological constant plays a role only at late time, low redshift $z \lesssim 1$. At higher redshift, the matter density which scales like $(1+z)^3$ was dominant. But this is also roughly the redshift when galaxies have formed and density fluctuations became large. So this would solve the so called coincidence problem: 'why now?'. The cosmological constant was negligible at all higher redshifts and will be the only relevant component in the future. Only at the present time, matter and the cosmological constant have similar contributions to the expansion of the Universe.

However, relativistic numerical N-body simulations have shown that this back-reaction can affect the expansion law in a Universe similar to ours only at the percent level [16, 17]. Therefore, while backreaction is relevant for so called 'precision cosmology', the effect is too small to account for cosmic acceleration.

It is of course also possible that a slowly evolving scalar field with an energy momentum tensor dominated by potential energy, a so called 'quintessence field', plays the role of a cosmological constant. This is postulated to have happened in the very early Universe during the phase of 'inflation' where the fluctuations which we observe in the CMB have been generated out of quantum fluctuations in the scalar field responsible for inflation.

Apart from a dark energy component which violates the strong energy condition, so that accelerated expansion is possible, researchers also consider modications of General Relativity on very large scales. This can be done via a scalar-tensor theories of gravity, by introducing a new vector field, vector-tensor gravity or via second spin-2 field, bimetric gravity. In all these theories care must be taken in order not to spoil the excellent agreement of observations with GR on galactic and smaller scales. This is usually achieved with so called screening mechanisms.

An overview of the plethora of possibilities can be found e.g. in [18, 19]. However, none of the proposals are more economical than a simple cosmological constant, and none of them agrees better with present data. Furthermore, even if these suggestions assign the present accelerated expansion not to a cosmological constant, they do not explain why then the cosmological constant should vanish.

Despite the excellent fit of ΛCDM to cosmological data, here are some interesting 'tensions' in recent cosmological measurements of the Hubble constant H_0 and in the amplitude of cosmological fluctuations. When measuring these quantities with different experiments which should yield the same result, one obtains conflicting values, which differ in the case of H_0 by as much as five standard deviations. Might this be a hint that the underlying theory, the ΛCDM model, is wrong? Or is this simply the effect of some un-accounted for systematics in some of the experiments? This discussion is intense and at present there is no agreement in the scientic community. However, in the case of H_0 there are relatively solid arguments that late time modifications of the model at $z \lesssim 2$, as they would be needed for a dark energy different from a cosmological constant, cannot solve the tension.

4 Conclusion

According to our present understanding of QFT, the vacuum energy is arbitrary and cannot be determined. However, during a phase transition it is expected to change by an amount of the order of the energy scale of the phase transition. According to Einstein's GR, vacuum energy contributes to the cosmological expansion exactly like a cosmological constant, so that it cannot be distinguished from the latter by any experiment.

More than 20 years ago, a non-vanishing vacuum energy of about $(10^{-3}\text{eV})^4$ has been measured, and this has been confirmed by several very different follow up experiments. We have absolutely no understanding of this highly fine tuned value which does not agree with any high energy physics scale. Why should vacuum energy just now, when human beings try to measure it, become relevant for the expansion rate of the Universe? It was irrelevant in the past and it will be the only relevant term in the future.

- Is the observed acceleration of the Universe not due to vacuum energy but to some modifications of GR on large scales?
- Do we have to invoke the 'anthropic principle' to answer the 'why now' question, see [20] or [21] for details: vacuum energy has the largest value possible which is still compatible with the existence of human beings. Or is the idea behind such an argument, that all possible Universes do exist, giving up the predictive power of physics?
- Might the strange value of 10^{-3}eV have something to do with the neutrino mass scale?
- Might it be a low energy manifestation of quantum gravity, which we usually expect to manifest itself only at very high energies close to the Planck scale?

I consider the vacuum energy and the role it plays for gravity the biggest open problem of theoretical physics at the present time.

Acknowledgement

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Directed by our members Anna Beliakova (UZH) and Tatiana Samrowski (UZH), the Junior Euler Society (JES, UZH) is the University of Zurich's Institute of Mathematics outreach program. Since its creation in 2007, it has continuously increased in popularity. The program offers school children from 8 to 18 years old the opportunity to engage in mathematics beyond the school curriculum.

In this article Tatiana Samrowski speaks to us about this highly sought-after outreach activity and how it first came about.

Presenting the Junior Euler Society

Valuing the needs of gifted children

Anna Beliakova first had the idea of creating JES in 2007. It all started when Anna, as a representative of I-Math UZH, attended an exam lesson which impacted her. An exam lesson is an exam which ongoing high school teachers are obliged to pass.

During this lesson Anna came across some of the limitations that mathematically talented students face at school. She remembers a highly gifted student surprised the teacher by providing the right answer just before she had finished reading out the question. Assuming this was "not normal", the teacher decided to completely ignore the talented student and to slowly solve the problem for the rest of the class time. Anna was left thinking that if this was occurring during a class which had been especially well-prepared, as the teacher was under exam conditions, it was very likely that the situation was probably much worse during normal teaching time where less preparation is involved.

Credit: JES UZH

Credit: JES UZH

At this point Anna thought about creating a space where talented young people, under scientific guidance and together with like-minded individuals, could solve mathematical problems independently and develop their own solution methods. She discussed the idea with Thomas Kappeler, who unfortunately recently passed away and who is dearly remembered, and together they launched JES.

Rapid Growth and high demand

When JES first started in 2007, the program took place once every two years and consisted only of a single class made up of both, seventh and eighth grade class students. Nowadays, which is fifteen years after the program was launched, there are four courses operating throughout the year for years: U10, U12, U14 and U18, as well as the JES Olympiads A and B for the children, who are interested in competitions. There is also the Fruehstudium (Early studies) course, which is very similar to university lectures, but not as intense and abstract. This course is intended for young people who are considering pursuing their studies in mathematics, sciences or engineering and would like to experience university lectures. In addition, there are also programming courses and different events such as Summer and Winter Schools.

Although the number of activities has considerably increased over the years, due to the COVID restrictions, this year only around 200 young participants could be accepted in total as opposed to 350 before the pandemic. Indeed, not only were the number of participants limited in each class, but also the traditional Winter and Summer Schools did not take place because of the pandemic.

Demand for all JES courses is very high, so the program doesn't really need to be advertised or promoted. It is not really necessary as there is even a long waiting list. Although demand is high for the courses at all levels, the class sizes are based on an age pyramid structure. This is mainly due to the fact that many of the younger participants are brought in by their parents, which means the number of children in each class decreases as they get older. Most of the participants who remain in the older

Credit: JES UZH

groups are those who are genuinely interested.

Increased number of girls

It is also important to point out that the number of girls participating has also significantly increased over the years. When JES first started there were only two girls, the number gradually increased and currently, there are several groups that have either equal number of girl participants or some groups with even over 50%. The older groups tend to have a higher percentage of girls, this is because the girls who join JES from an early age tend to stay throughout the program. Girls in particular enjoy finding themselves amongst like-minded individuals and meeting other girls who also like maths. They usually sit together; they feel comfortable, encouraged and also inspired by the women teacher assistant role models in JES. Some of our teacher assistants were themselves JES participants.

JES is for all

JES is opened to young people who are interested in maths, regardless of whether they are talented or not. There are no entry exams or requirements. There are children of all levels. There are also cases of young students who when they first arrive are not that good at the beginning and improve after the first year and sometimes, they might even find themselves top of the class. There are also others whose talents are revealed during the Olympiads too.

Olympiads: a highlight moment

There are many different Olympiads levels and involve international competitions. Starting from the Kangaroo level to the older groups like EGMO and MEMO. JES participants have received various medals, mainly bronze and honourable mentions, representing Switzerland in international competitions. JES has strongly enforced the Swiss teams and greatly contributed to placing Switzerland on the map in International Olympiads.

This year JES is co-organizing the Middle European Olympiad (MEMO) in Bern in August 2022. The last time it took place in Switzerland was back in 2012. This year MEMO expects to welcome 60 participants representing ten different countries. Two of six Swiss participants come from JES.

Every story is a success story

In JES, medal or no medal every story is a success story. Every participant is exceptional, and their contribution is just as important. Almost all students who stayed on from an early age, have been very successful and have taken different paths. Interestingly, from JES Olympiads, almost all of the students go on to study either mathematics or computer sciences. From grade 18 and the Fruehstudium course, they usually go on to science or physics, mainly because most of them want to ensure they have the required level in mathematics to study sciences.

The future

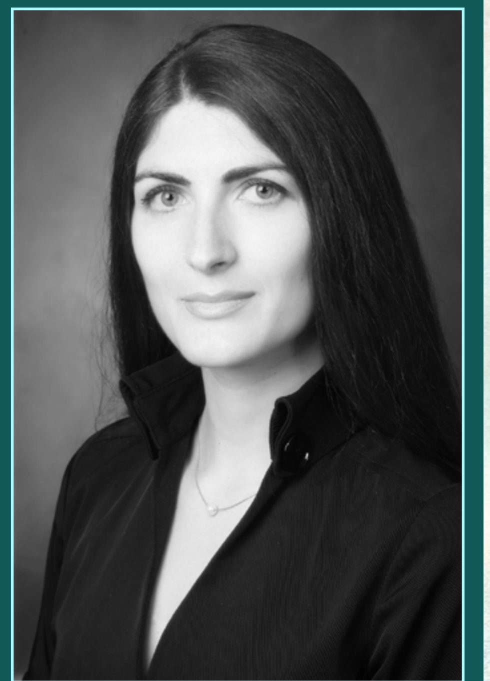
As for the next steps for JES, it will be extended to Linguistics. Linguistics is a logical science; it is not so much the structure of the language but rather the logic of thinking.

We look forward to continuing to encourage JES student's growth in mathematical reasoning and problem solving.

Credit: JES UZH

JES directors:

Anna Beliakova (UZH)



Tatiana Samrowski (UZH)

From an interview by Mayra Lirot
March 2022, Zurich/Online

JES interviews

Philipp, Alisa and Evelyn
Current students

Philipp, Alisa and Evelyn are currently students at UZH's JES and they spoke to us about their experience and about how JES has helped them.

Do you have any other activities outside of school apart from JES?
Philipp: *Yes, I swim, I also go sailing and play the piano.*

Are your best results in maths at school?

Philipp: *Yes, by far and after maths is sport .*

Can you tell us about how you first heard about JES?

Evelyn: *I discovered it on the internet out of pure interest in Mathematics and was interested immediately. I found that at school the work was sometimes too easy.*

Why did you choose to join the program and what were your expectations at the beginning?

Evelyn: *I always had a passion for maths. It is one of my favourite subjects at school, besides Biology, French, Computer Science and Sport. I felt like I needed to improve my skills in order to prepare for competitions.*

Alisa: *At the beginning I didn't really have many expectations, but I perhaps thought it was going to be similar to school. However, even though I knew there would be competitions, I wasn't expecting the high level of practice and help in preparing for these competitions that there is at JES.*

How did you find the level when you first started?

Alisa: *When I first started, I found it was not as easy as school, but it was still not too difficult. Then gradually, it got harder and harder. It wasn't as hard that I couldn't do it, but I did have to figure it out...*

What do you mostly enjoy about JES?

Evelyn: *Being together with other students who are interested in maths and competitions. At school there weren't many other students who liked maths. And the teachers at JES are great!*

Alisa: *I really like that the teachers are women, as a girl I find it's really inspiring. I also like the teacher's approach because they help you to help yourself. What I mean is they will not come and give you the answer, instead they will help you find the way to the answer so that you can work it out yourself.*


Philipp


Alisa


Evelyn

Can you tell us about a special moment in JES you specifically remember?

Philipp: *Visiting the University of Zurich for the first time because I was very young and for me to be at the university was a really special and memorable occasion. I remember being impressed by the amount of people around, the size of the campus and the rooms with all the modern equipment like computers.*

How would you say JES has helped you?

Philipp: *It has allowed me to see the level of other kids at the competitions and in class, which increased my interest in maths even more.*

Evelyn: *JES has helped me a lot to develop my math skills. And it made me love mathematics even more, including competitions.*

Alisa: *It has given me more of a systematic understanding of life problems. Another important part for me has been the people. There is a great community who shares the same interest and see each other fairly often in the lessons.*

What suggestion can you make to improve JES?

Philipp: *There is only one thing I can think of, and that is that it is only in Zurich. I think that there are probably other kids in Basel, for example, who might want to join JES but they may not be able to because of the distance. So, maybe an idea could be that some classes are also partially held online to allow people who are not in Zurich to participate as well.*

Do you have an idea of what you would like to study in the future?

Evelyn: *Certainly Mathematics, in combination with another science. I think I will begin in Basel or Zurich. Some semesters abroad, for example in Cambridge, would also be great.*

Interview with JES students
April 2022, Zurich/Online

Interviewed by Mayra Lirot
NCCR SwissMAP

Alumni Corner

Pavel SAFRONOV (University of Edinburgh)

Pavel completed his PhD degree in 2014 at the University of Texas. Then, after a position at Oxford and Bonn, he joined SwissMAP in 2017 firstly at UNIGE for six months in Anton Alekseev's Group and after at UZH in Alberto Cattaneo's Group. Pavel is currently a Lecturer at the University of Edinburgh where he started in 2020.

From early on in his career, Pavel has been recipient of various awards such as the 2012 Frank Gerth III Graduate Excellence award, the 2014 Frank Gerth III Dissertation Award, and most recently, the 2020/2021 André Lichnerowicz Prize in Poisson Geometry, which he received for his fundamental contributions in shifted Poisson geometry and in deformation quantization theory. He advanced the understanding of classical notions of symplectic reduction and of Poisson-Lie groups within the framework of shifted Poisson geometry. His results on deformation quantization led to applications to the Bonahon-Wong conjecture on Azumaya locus of the Kauffman bracket and to Witten's conjecture on finiteness of skein modules in quantum topology.

We caught up with Pavel in Geneva at the end of June 2022, during the conference "*From Subfactors to Quantum Topology - In memory of Vaughan Jones*" where he gave a talk on: *Skein modules for generic quantum parameters.*

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

What is the topic of your research?

In the talk I spoke about my work in that area and about some objects called skein modules. A part of my talk was about explaining a conjecture of Witten, which I proved with my collaborators Sam Gunningham & David Jordan. Skein modules are certain spaces you associate to manifolds, which are obtained by counting links. They are a part of quantum topology. The upshot of our work and this is what I tried to get to towards the end of the talk, is that quantum invariants are usually complicated and more interesting than ordinary classical invariants. However, it turns out that skein modules for generic quantum parameters can nevertheless be understood through classical geometry, and we can use classical, rather than quantum, tools to understand them. This is how we proved this conjecture.

Why is it interesting and important?

Part of my topic of research is quantum topology and Vaughan Jones's work was an important precursor to the foundation of quantum topology.

My recent research involves various quantum invariants of manifolds. What I'm trying to understand is what they actually capture about the manifold. As they don't capture everything about the manifold, i.e., they capture only some aspects, I'm trying to narrow it down precisely: what does one need to know about the manifold to extract these invariants? How sensitive are they to various structures on manifolds? Part of the field of quantum topology is to understand these kinds of invariants and the structure behind them.

Who has mostly influenced you in your life and which perhaps led to an important change?

My PhD advisor whom I would say formed a mathematician out of me. I have a bachelor's degree in physics from Saint Petersburg State University and obtained my PhD from the University of Texas. I was initially interested in string theory and its theoretical physics aspects. However, as the physics and mathematics departments were in the same building it was very easy to talk to mathematicians. This is how I started talking to David Ben-Zvi, who later became my advisor and who transmitted on to me all his incredible enthusiasm and great interest in the field.

My advisor always encouraged me, the same way I do with my own students now, to go to seminars outside of my field. This is something I continue to do.

What is the most surprising thing you've encountered in your career?

I would say it is part of what my advisor explained to me about how various aspects of mathematics are connected and about how it is useful and important to have a perspective in different fields. For example, in the talk I gave this week I used ideas from several fields. Even though the main result was in topology, there were also some results from analysis. This was quite unexpected for topologists as most low-dimensional topologists are not familiar with those tools. However, as my collaborators and I are not really quantum topologists we have a slightly different point of view and being familiar with those tools, we were able to realize that those techniques could be applied. What was unexpected to me during my PhD and during my Postdoc years, was how easy it is to connect fields and to understand that they're all referring to the same mathematics.

Various aspects of mathematics are connected and it is useful and important to have a perspective in different fields.

How do you go about stepping out of your own field?

My advisor always encouraged me, the same way I do with my own students now, to go to seminars outside of my field. This is something I continue to do. Recently I've been learning and attending seminars on low-dimensional topology and learning about algebraic aspects of differential equations. Although initially it can prove challenging as it is difficult to understand the talks, I try to start by learning the keywords. Then, gradually I begin to understand certain parts. Even if I don't necessarily grasp what the speaker had initially set out to present but rather only parts, these small parts actually become very relevant to me afterwards.

What is your favourite SwissMAP memory?

Its uniqueness. I don't really know of any other country with a similar kind of model, facilitating interactions and collaborations between different universities in the way that SwissMAP does. I found that aspect quite beneficial for my career and my research.

Firstly, I was able to benefit from both Geneva and Zurich. Secondly, events such as the Winter Schools were great opportunities. Starting the day with the mini-courses, then

the networking and talking to people from different locations and finding out what they were doing. Then skiing and coming back for more talks in the evening and being able to discuss with the speakers.

Nowadays I still have links with SwissMAP mainly on two levels. Firstly, through the SwissMAP Research Station. I am glad that the SwissMAP Research Station is there and that there are so many conferences throughout the year. Secondly, I am currently mentoring a Postdoc, Jan Pulmann, who is still a member and collaborating with Florian Naef, who is now in Ireland, both of whom I met through SwissMAP.

What are your hobbies and interests in your spare time?

I enjoy playing the piano. Actually, before I studied physics and mathematics, I was preparing to be a professional pianist. I find it really fascinating that several mathematicians are also musicians. For example, in the Oberwolfach Centre in Germany, there is an entire music room with a grand piano and a cello.

Who is your favourite person in history, and what inspires you from them?

When I was studying physics I read the autobiography by Richard Feynman, the Nobel Prize in Physics 1965. I found he was really fun and whether accurate or not, I was fascinated by the persona he created in the books. I was also really impressed by his list of diverse interests like playing the bongo drums and learning Italian.

This week I was also impressed by Vaughan Jones and his many interests like music, choir and windsurfing amongst others...

Like them, are you also a person of many interests?

In a way, as well as playing the piano, I also love skiing, hiking, camping and cycling and outdoor activities. I like to be curious and to get excited about various things. I would say my advisor taught me those qualities.

Do you have a project or a dream you would like to achieve on a personal level?

I don't really know of any other country with a similar kind of model, facilitating interactions and collaborations between different universities in the way that SwissMAP does. I found that aspect quite beneficial for my career and my research.

I like to be curious and to get excited about various things. I would say my advisor taught me those qualities.

I just got a permanent position as a Lecturer so would like to settle down. I also have some plans to become better at languages. I would like to improve the German I learnt when I was in Zurich, as well as to learn some other languages. One of the languages I started learning during lockdown was Mandarin. Before the pandemic I really wanted to travel to China and experience it properly which implied speaking the local language.

And in mathematics?

There is a big area of representation theory which goes by the name of Geometric Langlands Program. Recently people have connected that to objects to number theory and together with my collaborators, in particular my former advisor David Ben-Zvi, we have been exchanging ideas about connecting that to topology. This is a big program, and it will definitely take a few years to even formulate the conjectures and probably many more years to actually prove something. It is quite a big area and big motivation in my research.

Conversation with Pavel Safronov
June 2022, Geneva

Interviewed by Mayra Lirot
NCCR SwissMAP

Industry and Academic paths

Simone Chiarello

In 2020 Simone joined a large financial institution. Previously, he completed his PhD at UNIGE in Andras Szenes' Group as a SwissMAP member.

The title of his thesis was *Equivariant intersection theory on the moduli space of rank 2 Higgs bundles*.

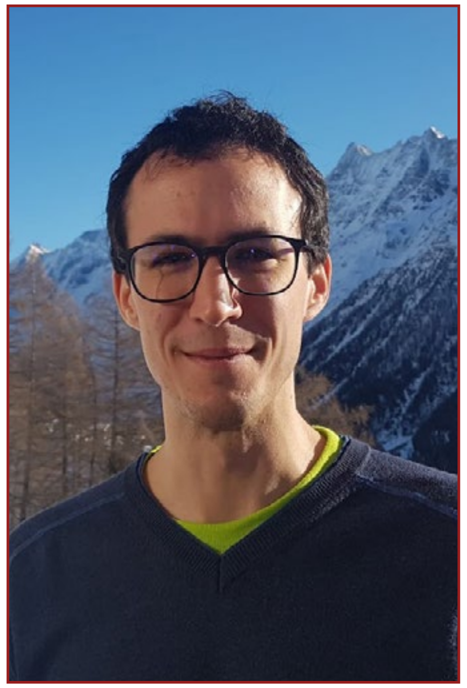
It was the summary of a five-year project which allowed, among other things, to find effective residue formulas for the equivariant integrals on the Higgs moduli spaces, and to a new formulation and partial proof of the classical P=W Theorem in rank 2. This approach might be applied to higher ranks as well, for which P=W is still an open problem.

Samuel Monnier

Samuel worked in theoretical physics, mainly studying the constraints anomalies put on quantum field theories and string theory. He completed his PhD at UNIGE and then held postdoctoral positions in the US and in Europe. He joined SwissMAP as a postdoc (UZH, A. Cattaneo's Group) and as a Senior Researcher (UNIGE, A. Alekseev's Group).

He started working at G-Research in 2019 as a quantitative researcher ("quant") and is now a senior quantitative researcher. G-Research is a successful quantitative finance research firm, whose core business involve researchers developing systematic trading strategies. They use algorithms and machine learning to predict movements in financial markets and discover inefficiencies.

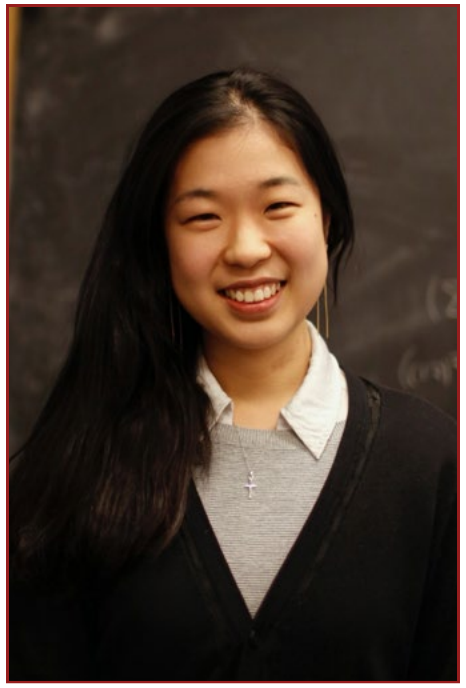
Sébastien Ott



Sébastien Ott is a mathematician, his research mainly deals with probabilistic approaches to problems arising in classical statistical mechanics, with a particular focus on the study of correlations and phase coexistence.

Sébastien first joined SwissMAP as a PhD student (UNIGE, Y. Velenik's Group) and is now a Senior Researcher (UniFR, I. Manolescu's Group).

Yilin Wang



Yilin Wang is a mathematician working on probability theory, complex analysis, and related problems in mathematical physics, she focuses on connections among random conformal geometry, geometric function theory, and Teichmueller theory.

Previously in SwissMAP, Yilin was a PhD student at ETH Zurich in Wendelin Werner's group. Then in 2019 she joined MIT as a C.L.E Moore instructor. Yilin is currently at Berkeley.

Yilin is the recipient of several awards and prizes: in 2018 the SwissMAP Innovator Prize, in 2020 - ETH Zurich Medal for her doctoral thesis, and more recently in 2022 the Maryam Mirzakhani New Frontiers Prize.

Industry vs. Academia
February - March 2022, Geneva

Interviewed by Mayra Lirot
NCCR SwissMAP

Simone Chiarello

Why did you decide to leave academia and join the industry?

Since I started University at the Scuola Normale Superiore (SNS) in Pisa in 2010, I had dedicated all my time and efforts to research and towards an academic career. During my Master, I began by specializing in algebraic geometry and topology and then in general in the geometry framework. I was always quite certain I would remain in academia.

The turnaround moment for me was during the last year of my PhD which also coincided with the arrival of COVID-19, and just as many other people, I found myself in lockdown in early 2020. Although at this point I was extremely stressed writing my thesis and struggling to get more results, during this time I also felt I grew closer to my family. I also had time to think about my life and my priorities and I realized that the academic path presented certain obstacles which were not compatible with my personal situation.

Although I was very glad and honoured to receive two postdoc offers in two extremely prestigious universities, one for 18 months and the other for two years, one in Boston (thanks to the SwissMAP Early Postdoc Mobility Fellowship) and the other in Bonn, I could not help to think that after this position there would be another one, then perhaps a second and a third one, before finally finding an assistant professor position. This lifestyle would mean that I would have to travel around the world, not knowing where I would go next.

Furthermore, even though I had enjoyed dedicating every day of my life to maths during the previous 12 years, I feared that with the passing of time, I might regret not doing other things too, instead of just researching a tiny fraction of science without any certainty of what final impact it would have.

The situation created by the pandemic triggered all this questioning, plus on top of everything, I knew I would probably be less well paid in academia than I would be in the industry.

Was it difficult to suddenly stop doing maths after such a long time?

I haven't actually stopped doing maths, I still do it but in a different way. Although the purpose is no longer solving a huge problem which has been open for years, I can say that now I do it for a purpose, either for something connected to industry or as part of a personal or IT project.

Further, as I know that what I am doing will be useful to other people in totally different areas, it motivates me even more. And although the research I was doing for my PhD was also useful, it ultimately mainly served for people to do more research, similar to a chain effect.

Can you tell us about how you apply the things you learnt in academia to your current job?

I clearly do not apply equivariant cohomology or Higgs bundles, but what I do apply is the method of research. I also apply complex mathematical skills like differential equations, finite difference equations, or stochastic calculus.

Although in industry as in academia the answer is not going to be found in a book, they still each refer to very distinct types of proofs. The difference being that in academia you have the classical mathematical proofs, with reasoning, referencing other results and through logical passages going to the final statement, and even though this method can also be used in industry for some cases, in general in industry, the most important factor still remains practical proof. In order to prove the result of a complex calculation, you need to simulate it, or even apply it to a real-world situation and see whether it gives value.

What difficulties did you encounter during the transition?

To begin with I felt quite frustrated because I went through several interviews and I realized that despite having a PhD, I was not always able to answer some very basic questions during the interviews, or at least not in the way the interviewer was expecting.

What in your experience are the greatest workplace culture differences between both worlds?

If we take pressure for example, we can say that the short-term pressure is definitely higher in industry than in academia. In an industry job you need to deliver on a daily basis, or you will be approached by the manager or even worse by your clients. On the other hand, the long-term pressure is lower than in academia. As an example, in academia after having worked on my PhD for five years, towards the end I remember feeling terrified of not getting results and of not publishing enough.

However, even though the workload is higher in industry as I constantly have to deliver, it actually feels like it's less because it's managed more efficiently.

There is also a difference in terms of responsibilities. In the industry what you do is actually used by others, so this means you have great responsibility towards others and this motivates you to do a good job, whereas in academia you are much more autonomous.

The relationship with colleagues also differs. Working in the industry is of course less relaxed, meaning you don't joke around with your colleagues as you would with your peers during your PhD. However, this can also be good because it can bring a good balance and set boundaries between life and work.

What does your work involve on a daily basis and how is it different from the academic research?

In the bank I maintain and develop various computational systems related to specific financial products, interest rates derivatives or interest rates products in general. It is not only computational, because computation in industry is just one part of the entire story, there is also data fetching, connection to servers, elaboration of the data, filtering data, processing data. This is only the calculation part, then there is the delivery of results to the client, traffic management and capacity management.

I am in charge of all these informatic, automatic and mathematical aspects. So on a daily basis, I may receive requests to change a computation because perhaps a particular calculation does not fit anymore, or because something has changed in the world, or in the bank or in the team. There are different levels of changes which require changes in the calculation. The system needs to be constantly maintained, changed and adjusted to the everchanging new requirements. This is what I do, coding data checking, data calculating, curves checking results.

What in your opinion is the most important aspect you have gained from the move?

Probably the most important aspect is the work life balance, but I would also add security. After all that there is also the salary aspect.

What strengths and personal qualities do you think you need to work in the industry?

You need to be extremely focused on the result and do whatever it takes to reach it. You need to understand that studying is the tool but not the purpose, whereas in academia studying is basically both the tool and the purpose.

It is also important to understand that going to industry from academia does not mean that you will be doing something of less value or prestige. I believe that sometimes leaving academia to join the industry can be mistakenly perceived as a failure. This is absolutely wrong!

You need to be humble and understand that carrying out easy tasks, or what could appear to be easy tasks, is not something that will put you down. Easy tasks are probably the most important ones. In fact I learnt this from my PhD advisor in Geneva, who said that when something was easy you had an even a greater responsibility to do it very well, and this is when the easy task becomes difficult.

What advice would you give to someone hesitating between both paths?

Firstly, I repeat what I said earlier, It is not a failure. It is a choice which deserves as much respect as any other choice.

Then, I would also say, do not think that you are only good for research. People in academia are good for many other things too, and they also have great value outside academia. So, academia is not the only option. Finally, I would suggest to just dig in and to try to find out and understand what is currently being done in the industry. Perhaps take the phone, reply to the recruiter's emails and talk to people, particularly to those who are outside academia. If you don't know what there is on the other side, you cannot really choose. Don't be shy and speak up and ask.

I'm very happy, I don't regret my choice at all.

Samuel Monnier

When & why did you decide to leave academia to join the industry?

In 2015, I attended a quant workshop organised by G-Research. The most interesting part of the workshop was the chance to talk to a few researchers. They sounded smart, and at the time surprisingly for me, they seemed very happy with their job. This was the first time I began to consider a move to the industry as a possibility. I had also heard about their ruthless selection process, and I really didn't feel confident enough to apply at the time. Instead, I decided to learn more about the job of a quant and trained myself seriously in the relevant fields (statistics / computer science / machine learning). Then in 2018, as my position in Geneva was coming to an end, I thought it would be the good moment to try the move. I applied to various quantitative finance companies and managed to secure an offer in G-Research.

What difficulties did you encounter during the transition?

As mentioned, I was attracted to the job, but not very confident about the chance I would have of securing it. In particular, quant interviews generally feature heavily math olympiad style problems, something I have never been very good at. I practiced these furiously during my preparation, and I ended up doing just well enough to avoid them eliminating me.

I noticed that my age (38 at the time) was a problem in some companies, but fortunately this was not the case in the companies that offered the most interesting jobs.

What in your experience are the greatest workplace culture differences between both worlds?

I think workplace culture can vary dramatically from company to company, and this is something to be mindful about when interviewing for a job. Interviews generally involve some time when the candidate can ask the interviewer questions, asking questions during the interview can be a good way to find out about the workplace culture. It is also a good idea to prepare these questions carefully and to try to gather beforehand, as much information as possible about the company and the position. I can't stress enough that not asking questions during an interview gives a terrible impression and could even appear as if you did not really care about the position.

At G-research, the culture is probably as close as it gets to academia. People are generally nice and helpful. It is understood across the company that research takes time and there are little external pressures or deadlines imposed on researchers. Most of the pressure is internal and comes from being surrounded by smart and successful colleagues.

The starkest contrast with academia is that knowledge is not freely disseminated across the company, let alone into the outside world. As a leak to a competitor would directly affect the profitability of the company, this is something taken very seriously. Yet, this is implemented in a fairly sensible way that does not seriously impact your own research. As you become more senior, you also get entrusted with more information.

Maybe another difference with some domains of academia is that the research is mainly carried out individually, under the supervision of a manager. Collaborations happen when they are meaningful, but they are not the rule.

What does your work involve on a daily basis and how is it different from the academic research?

As a quant researcher at G-Research, we're lucky that almost all of our time is devoted to research. Exceptions are interviewing candidates and occasional seminars/meetings. More concretely, a substantial fraction of the research time is spent writing code, either to obtain/transform/analyse data, to design algorithms exploiting this data or to analyse their behavior. This is experimental research, and experiments are designed through coding. A fraction of the research time is also devoted to pure thinking, pen and paper calculations and reading the literature, although arguably quite a bit less than as a theoretical physicist.

The type of research I am carrying out as a quant is quite different from my past academic research. Quantitative finance is a messy experimental science in which there aren't many clearcut "truths". Good ideas are not guaranteed to work, and most of the phenomena observed cannot be clearly explained. Counterbalancing this, the research output does not consist exclusively of ideas and knowledge, but of actual algorithms interacting with the outside world, and there are very clear metrics for measuring their success.

Regarding the daily routine, it is worth mentioning that according to how important your role is to the business it can make a crucial difference in how pleasant your daily work is. At G-Research, quants are the core of the business, and as a result we're lucky to have extensive support available to make our job (and life) easier. This is also something important to find out when applying for a new job.

What in your opinion is the most important aspect you have gained from the move?

Having a family, the main gain has been a stable job, free from financial worries.

I'm also happy not to have lost the creative aspect of research, which is what I was fearing the most during my job search.

Finally, unlike in academia where good research may or may not get immediate recognition, there is the added bonus that at G-Research, successful research is taken very seriously, and a lot of resources are made available to deploy it as fast as possible. Having your algorithms deployed in production and interact with the world is a really exciting feeling for which I think there is no equivalent in my previous work as a theoretical physicist.

What strengths / personal qualities do you think you need to work in the industry?

I think it is very hard to speak generally. As a quant, I would say that many of the required qualities are similar to the ones required in academia:

- Strong quantitative skills;
- Ability to discern problems that are interesting but simple enough to have a feasible solution;
- Strong resilience to failure. We are working on very difficult problems and a high proportion of the projects fail, not always for obvious reasons.

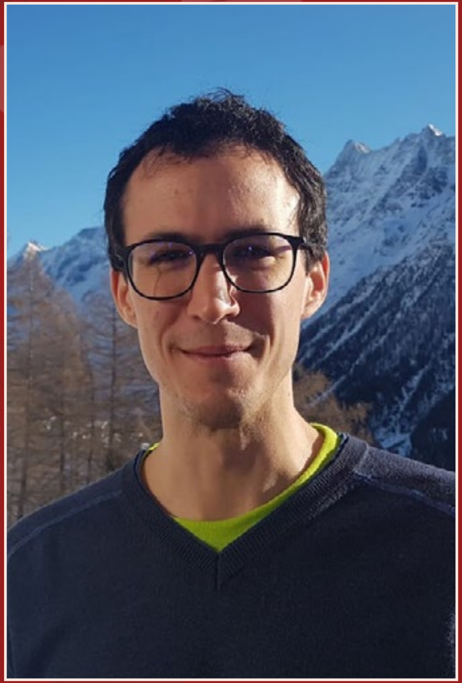
A difference with my previous academic job is that one should really enjoy writing code, because quantitative finance is an experimental science and writing code is the only way to carry out experiments. It is also very important to keep a practical mindset and have a fast feedback loop when testing ideas, because even the best idea may fail unexpectedly. Unlike what is probably the case in much of the industry, communication and soft skills do not matter very much beyond the basics, as quants are evaluated based on their research output.

What advice would you give to someone hesitating between both paths?

I would advise them to try to find a way to stay on in academia for a bit longer if possible, and to try to gather information/skills until they are convinced either one way or another. If the aim is to continue to do serious research in the industry, my feeling is that such jobs are rather rare and that there is significant competition to get them. The more prepared the better. If the aim is to switch to a completely different job, I can't really offer advice.

I would also encourage them to reach out to people in the industry to get a better idea of the kind of jobs available and what they entail. Most people are happy to help or provide advice. Moreover, some companies reward employees referring successful candidates, so it may even be in their interest to help you.

Sébastien Ott



Did you always know you'd pursue the academic path, or did you ever consider other possibilities?

I had never considered staying on in academia before my PhD. In fact, when I started doing mathematics, even before my master's degree, I had always imagined myself mainly in the industry and had never really considered academia. However, this started to change when during my master's degree I became very interested in some of the problems I was working on. By the time I got to my PhD, this interest had increased substantially. It was at this moment that the revelation came to me, and I decided I would stay on in academia. In the end I never had the opportunity to apply for an industry position because when I finished my PhD, the next step had already been planned.

What motivates you most in your environment?

I think firstly it is the freedom that you have in academia. You are free to choose what you want to work on and what you want to think about, and this is very motivating.

I would say that another very important aspect is that there are other people around you, who are interested in the same kind of topic as you. This is an essential point. Firstly, it is an excellent way to nurture ideas and to share different points of view, it could also lead to collaborations and even to help avoid getting stuck on something that in the end was not going to work. Secondly, as you have to explain what you are doing to someone else, the process could help you to define and organize your own thoughts. Finally, writing long term projects with other authors is very motivating. Particularly during times when you get discouraged because something is either not working, or you don't have time, or you run out of ideas. Having other people working on the same project can really help to bring in new ideas and to motivate each other.

Can you tell us about some of the most rewarding moments?

One of the most rewarding moments was probably finishing writing the first article. Indeed, the first time you finish writing an article and you see your name on it, is definitely a very special moment. Another very gratifying moment is the first time you see your name appear on a theorem on someone else's presentation. These moments are like recognitions of the work.

What in your view are the most important advantages of the academic path?

I think this connection and relationship with people. Although this may also be present in the industry, the main difference in academia is you are doing it because you want to do it. I really love research, it's like the job and the hobby merge into one. In academia you really do what you like, and in the industry, you do what you have to do.

What are the greatest challenges you think people face in academia?

The obvious one is dealing with failure. When something does not work the way, you had expected, and you take this failure upon yourself, as you are the one who chose your own research topic. When it doesn't work you have to deal with it, that is certainly one downside.

The other one I would say, is the uncertainty before getting a permanent position. Living with the uncertainty of moving for a long time, between short term positions and not knowing where you will go next, nor how it will end, or even if you will be able to remain in academia, this is an important drawback.

How do you deal with failure, because most of the time you probably don't get it right?

99% of the time you do not get it right! The fact that you're really passionate about what you want to research facilitates the process of dealing with failure. I think essentially you get over it because you like the topic, and you want to research it.

Thus, the fact that you fail on one path doesn't discourage you from still wanting to understand what you had set out to understand in the first place, and this unresolved issue continues to drive you further into research. Consequently, failure can be perceived as having chosen the wrong path, so you simply step down on the way to the top of the mountain and choose another path.

And what about dealing with the uncertainty?

I think if you really like what you're doing you don't ask yourself too many questions. However, at some point, one must take a decision and it could be that ahead of time, one could fix either an age or an amount of time that one would be willing to spend in short term positions, before having to decide whether or not to remain in academia. Sometimes decisions are also be influenced and shaped by life circumstances, such as for example family and security reasons. However, if you are not obliged to make a choice and if you really like what you are doing, the fact that you like what you are doing makes it much easier to decide. Personally, I will try and continue in academia and see how it goes.

Can you tell us about the pressure to publish?

When researching you always find something. Whether it's interesting or not, it's a different question. If you're really pressured to publish, you will publish more of those "findings".

If you just publish because you need to publish something, it could appear like you have tons of articles published, whereas in fact, you have very little in new information. I think this pressure of publication is not improving research.

What strengths and personal qualities do you think you need to remain in academia?

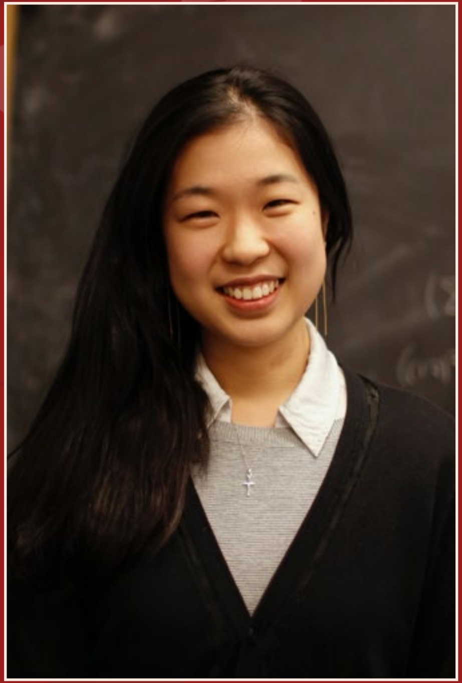
I think you need a well-developed ego. You need to be very confident, and confident that you can handle yourself and that you don't need someone constantly checking what you're doing. You also need to be fairly self-disciplined because you have a lot of freedom. Self-confidence and discipline are two very strong points that will make the academic path easier.

What advice would you give to someone hesitating between industry and academia?

I think doing a PhD is a good way of finding out if you like doing research or not. However, if after the PhD you are still hesitant, and you don't like the topic, or if you are unsure about wanting to pursue an academic path, then it might be better not to. I believe that if you follow the academic path, it should be because you are really interested by it, I don't think that the academic path is the one you should choose by default.

Another good way of choosing is by looking at what you want in life outside work. Determining if you are perhaps more interested by having a more settled lifestyle, i.e., if you value more having a life outside of work; or if on the other hand, you consider it is more important to work on something that you really enjoy and that stimulates you. I think this kind of questions could be helpful if you are hesitating between the industry and academia.

Yilin Wang



Did you always know you'd pursue the academic path, or did you ever consider other possibilities?

My decision to pursue an academic path was very last minute. When I finished my master's degree in Paris, I felt like the next natural step was to look for a job in the industry. Although I had always liked maths and it had always been my favourite subject since a very young age, I didn't really know what the academic path was truly like at the time, nor would I be gifted enough for it.

I remember feeling very unsure about how to write a resume, but still, I sent out around 20 applications from which I never heard back.

Thanks to my then future advisor, at this point, I realized that one of the reasons why I hadn't considered the academic path until then, was that I was working on a topic that might not fit my way of thinking and one cannot know it without trying. I found that when I slightly changed the direction of my research, I rediscovered the passion for maths. This redirection, coupled with the fact that no doors opened for me outside the academia, was like a call for me to stay on.

What motivates you most in your environment?

I think the driving forces for me are curiosity and working with a community. I always want to know the answer to a problem, there is an incredible satisfaction when you find the answer to a question, that nobody else knows, and you are able to come up with an elegant proof! These are of course very rare moments as most of the time it is not like that, but these moments are a reminder of the huge reward at end of the road. Then as I said, being part of the network is also another important aspect. Having colleagues who are located around the world, with whom you can meet and discuss with during international conferences. Colleagues who can understand you and share excitement and whose questions generate more questions…

What in your view are the most important advantages of the academic path?

I can only speak for myself though. I would say satisfying curiosity and admiring the beauty behind all the mathematical structure. Moreover, in maths there's a lot of absolute. You aim to produce something 100% correct (with assumptions clearly stated) and the correctness does not fade with time.

There is a very long-lasting satisfaction when seeing different pieces of math fit harmoniously together and our understanding has improved along the path.

Also, the knowledge that will also be beneficial for all those who will come after. There is a sense of being part of the history. I feel part not only of the community, but also part of the historical progress.

Other advantages you have are complete freedom to choose firstly, what you want to work on, secondly, when you want to work on it, and finally, whom you want to work with. I guess this is a feeling of being your own boss which allows you to be driven only by your own curiosity.

What are the greatest challenges you think people face in academia?

The general challenge is competitiveness. I think that compared to many other fields, in maths there is a very high percentage of people who hope to stay on in academia, and there are more people than jobs available. It is a reality that there are many passionate, talented people, and that competition is hard. After graduation you have to apply for a postdoc and maybe a second postdoc before you can aspire for a faculty position and stay somewhere permanently.

There is a lot of uncertainty, particularly for example for people who have family commitments, and can probably not afford to take the risk of finding themselves jobless after a couple of years. There is currently a lot of stress involved in job applications.

This can also affect how people perform their work, as maybe instead of focusing on tackling fundamental questions, which are very time consuming and risky, people might prefer to publish quickly. This is like going for the low hanging fruit instead of tackling the problems that they might really deeply care about. No one is to blame for this situation, we all have the pressure to publish.

What strengths and personal qualities do you think you need to remain in academia?

Again, I think maybe the most common quality is curiosity. It's something that we all have as a child but remains alive particularly in the mind of researchers. It is a need to know and understand the deep reason of the phenomenon they observe. Both, curiosity and perseverance are needed.

To this I would also add the importance of humbleness at different levels. Firstly, it is a reminder of the difficulties and of how little one can actually achieve. With this in mind, what becomes important is the work that you do, as oppose to how good you are at it. This would make you less sensitive to success and failures and help you going through up and downs. The work serves the advancement and the understanding of knowledge, so knowledge is the real boss.

Secondly, of humbleness within the community, as it will help not only to keep asking more questions but also to give credit to other people, no matter how big or small their contributions are. Humbleness benefits the community by sustaining an open, friendly, and healthy environment for ideas to flow. I think keeping in mind that there is positive role that you can play helps one to stay in academia as well since the community cherishes it.

In the US there is also a lot of talk about diversity and about what makes minorities feel bad in academia. One needs humbleness to recognize what is going wrong, and its more than just doing maths, it's a global consciousness of how to make this field that you love so much even better.

Do you think it is more difficult for women in academia?

I was very lucky. I was a single child and I found that there was not much talk about boys being better than girls neither within my family, nor at school. In fact, in the circle I grew up children generally want to achieve good grades. I think it's quite a consensus among most parents as well no matter the gender of their kid. I think I did well enough and I never thought about this gender issue.

However, entering higher levels and speaking to other female colleagues, I became more aware of such situations. I started to notice all the challenges that women, or other minorities in general, have to face.

However, I really honestly believe that people are not badly intentioned, but at the same time everyone is prone to their implicit bias. For instance, women researchers are often less respected. If they are talking, they are easier to question, interrupt or even worst not heard. It is like a very subtle mechanism which in turn, contributes to making minorities less confident and consumes their energy to fight against it internally and externally. So, it's a challenge.

Personally, I've been lucky as I've had a certain number of respectful collaborators, recognitions by the community, job opportunities and doors that opened.

So, you will obviously be staying on in academia?

Yes, there is no question. After Berkeley I will be going to IHES, Paris where I was offered a five-year junior professor position. I am very grateful for the opportunity.

What advice would you give to someone hesitating between industry and academia?

One thing I learned from my advisor and from my own decision-making processes, is that although we can try to gather as much information as possible to help us make a reasonable decision, the amount of information we can get will always be limited. There is something which I consider more important than trying to take into account all pros and cons and this is something I do when I need to make a decision, I really try to think about my own values and what is important for me.

A career is something we will be doing for very long time, so hopefully, what we do will be driven by our own values. I know many people ask themselves (including myself at the beginning): would I be able to find a job after if I do this? What about the future? But these worries are at best supported by statistical evidence. Every individual is different. I would say don't worry about them before they happen, go by your own values.

For instance, if you value more your work being put into applications immediately, then maybe it is more natural to work in the industry. Personally, I'm more driven by the intellectual satisfaction of seeing an elegant theorem, understanding things better, like the deep reason, but without thinking too much about how it impacts life.

Upcoming Events

SRS SwissMAP Research Station in Les Diablerets

Scientific Program 2023

JANUARY/FEBRUARY

Winter School in Mathematical Physics
January 8-13
A. Alekseev (Geneva), A. Cattaneo (Zurich), G. Felder (ETH Zurich), M. Podkopaeva (IHES), T. Strobl (Lyon 1), A. Szenes (Geneva).

New connections: chaos, field theory and quantum gravity
January 15-20
S. Shatashvili (Dublin & Stony Brook), J. Sonner (Geneva), E. Verlinde (Amsterdam).

Workshop on Quantization and Resurgence
January 29 - February 3
M. Mariño (Geneva), R. Schiappa (Lisbon).

Integrability in Condensed Matter Physics and Quantum Field Theory
February 3-12
V. Bazhanov (ANU), R. Kashaev (Geneva), G. Kotousov (DESY), H. Saleur (IPhT & USC), V. Schomerus (DESY).

Non-Archimedean methods in arithmetic and geometry
February 12-17
R. Cluckers (Lille & Leuven), A. Forey (EPF Lausanne), A. Szenes (Geneva), D. Wyss (EPF Lausanne).

Workshop in Statistical Mechanics 2023
February 19-24
S. Smirnov (Geneva).

MAY/JUNE

Geometric and analytic aspects of the Quantum Hall effect
May 7-12
A. Alekseev (Geneva), S. Klevtsov (Strasbourg), P. Wiegmann (Chicago).

Interactions of Low-dimensional Topology and Quantum Field Theory
May 21-26
D. Kosanović (ETH Zurich), R. Schneiderman (Lehman College CUNY), C. Schommer-Pries (University of Notre Dame), S. Stolz (University of Notre Dame).

Analytic techniques in Dynamics and Geometry
May 28 - June 2
A. Avila (Zurich), M. Cekic (Zurich), T. Lefeuvre (Sorbonne).

Helvetic Algebraic Geometry Seminar (HAGS) 2023
June 4-9
R. Pandharipande (ETH Zurich), A. Szenes (Geneva).

Effective theories in classical and quantum particle systems
June 18-23
M. Porta (SISSA, Trieste), C. Saffirio (Basel).

Junior Euler Society Summer school
June 28 - July 3
T. Samrowski (Zurich).

Euler Camp Summer school
July 3-7
J. Scherrer (EPF Lausanne).

AUGUST/SEPTEMBER

S-matrix Bootstrap Workshop V
August 20-25
A. Guerrieri (Tel Aviv), J. Penedones (EPF Lausanne), B. van Rees (Ecole Polytechnique), P. Vieira (Perimeter Institute & ICTP-SAIFR), A. Zhiboedov (CERN).

Categorical Symmetries in Quantum Field Theory (School & Workshop)
August 27 - September 1 & September 3-8
A. Cattaneo (Zurich), L. Döppenschnitt (Zurich), T. Dumitrescu (UCLA), D. Freed (Austin), L. Müller (MPI), C. Scheimbauer (Munich).

Mapping class groups: pronilpotent and cohomological approaches
September 17-22
N. Kawazumi (Tokyo), G. Massuyeau (Bourgogne), H. Nakamura (Osaka), T. Sakasai (Tokyo), C. Vespa (Strasbourg).

Quantisation of moduli spaces from different perspectives
September 24-29
N. Aghaei (SDU), A. Alekseev (Geneva), N. Orantin (Geneva).

Past Events

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

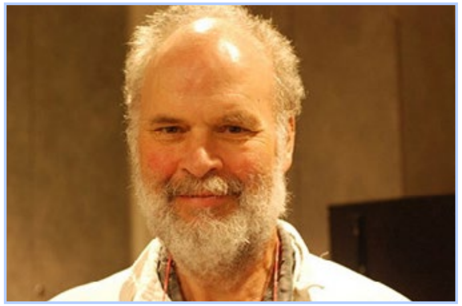
2021

XXth International Congress on Mathematical Physics (ICMP):
Plenary Talks, Thematic Sessions, Contributed talks, Public lecture, Human Rights Session, Awards Ceremony & YRS Mini Courses and Basic Notions

Other 2021 recordings available:

- **Cohomology of moduli spaces of flat connections**
- **Emergent Theories for Wave Turbulence and Particle Dynamics**
- **Geometry, Topology and Physics in Les Diablerets**
- **Vertex Algebras & Poisson Geometry**
- **Winter School in Mathematical Physics**

2022



From Subfactors to Quantum Topology
In memory of Vaughan Jones

Other 2022 recordings available:

- **Differentiable Stacks, Poisson Geometry and related geometric structures**
- **From Coadjoint Orbits to Black Holes**
- **Recent development in Link Homology**
- **Vertex Algebras & Poisson Geometry**

Awards & Grants

Pierrick Bousseau

Cours et Prix Claude-Antoine Peccot 2021-2022

Congratulations to Pierrick Bousseau (ETH Zurich) who received the Cours et Prix Claude-Antoine Peccot 2021-2022 which distinguishes the most promising young mathematicians.

Ruth Durrer

UZH Honorary doctorates 2022

The Faculty of Science honored our member Prof. Dr. Ruth Durrer, professor of theoretical physics at the University of Geneva, in recognition of her outstanding accomplishments in theoretical cosmology.

Ioan Manolescu

2021 Rollo Davidson Prize

Congratulations to our member Ioan Manolescu (UniFR) who was recently awarded the 2021 Rollo Davidson Prize in recognition of his outstanding work on critical physical systems in two dimensions, particularly the random cluster and Potts models.

Vincent Vargas

2022 George Pólya Prize in Mathematics

The Pólya Prize was awarded to Antti Kupiainen (University of Helsinki), Rémi Rhodes (University of Marseille) and our member Vincent Vargas (UNIGE), for a rigorous justification of the DOZZ formula for three-point structure constants in Liouville Conformal Field Theory.

Hugo Duminil-Copin & Maryna Viazovska

Fields Medal

The Fields Medal is the most prestigious award for mathematicians. It is awarded every four years at the International Congress of Mathematicians to two to four researchers under the age of 40 for their «existing work and for the promise of future achievement»



Chiara Saffirio and Vincent Tassion

IUPAP Young Scientist Prize winners

Congratulations to Stefanos Aretakis (University of Toronto) and SwissMAP members Chiara Saffirio (UniBas) and Vincent Tassion (ETH Zurich), recipients of the IUPAP Young Scientist Prize announced at the ICMP 2021 opening ceremony.

SwissMAP Innovator Prize

Barbara Dembin and Tomas Reis

2022

Congratulations to our members Barbara Dembin (ETH Zurich, V. Tassion's Group) and Tomas Reis (UNIGE, M. Mariño's Group) who have been awarded the SwissMAP Innovator Prize 2022.

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



Arthur Jacot and Maria Yakerson

2021

Congratulations to our members Arthur Jacot (EPFL, C. Hongler's group) and Maria Yakerson (ETHZ, R. Pandharipande's group) who have been awarded the 2021 SwissMAP Innovator Prize.

Pierrick Bousseau

ETH Zurich

Congratulations to Pierrick, who was already a SwissMAP member (R. Pandharipande's Group), and has been appointed Assistant Professor. He joined our SwissMAP Geometry, Topology, and Physics Research Project.

His research interests are Algebraic geometry, curve counting theories (Gromov-Witten, Donaldson-Thomas invariants), tropical geometry, mirror symmetry, deformation quantization, quiver invariants, cluster varieties.

Victor Gorbenko

EPFL

We welcome our new SwissMAP member Prof. Victor Gorbenko (EPFL). He is joining the five SwissMAP projects: Geometry, Topology and Physics, Quantum Systems, Statistical Mechanics, String Theory and Field Theory.

In his research he uses the methods of Quantum Field Theory, broadly defined, to solve fundamental problems in particle physics, cosmology, and quantum gravity.

Géraldine Haack

UNIGE

Congratulations to Géraldine, who was already a SwissMAP member (N. Brunner's Group), and has been appointed Assistant Professor. She joined our SwissMAP Quantum Systems Research Project.

Géraldine is a theoretical physicist, expert in quantum thermodynamics and quantum transport in nanoscale devices.

Peter Hintz

ETH Zurich

We welcome our new SwissMAP member Prof. Peter Hintz (ETH Zurich). He is joining the SwissMAP Field Theory & Geometry, Topology and Physics projects.

His research interests are partial differential equations, general relativity, microlocal analysis. His current research focuses on stability problems for solutions of Einstein's field equations.

New Members

Aleksandr Logunov

UNIGE

Welcome to our new SwissMAP member Prof. Aleksandr Logunov. He is joining the SwissMAP Statistical Mechanics project.

His research interests are harmonic analysis, partial differential equations, geometrical analysis. His current research focuses on nodal geometry, i.e., the study of the zero sets of the solutions to differential equations.

Vincent Vargas

UNIGE

We welcome our new SwissMAP member Prof. Vincent Vargas (UNIGE). He is joining the SwissMAP Field Theory and the Statistical Mechanics projects.

His research interests are: Probability, Mathematical Physics, Statistical Mechanics, Quantum Field Theory.

JES

Tatiana Samrowksi

Co-Director of The Junior Euler Society (JES)

We would like to introduce you to our member Tatiana Samrowksi (UZH, ZHAW). Tatiana Samrowski is alongside Anna Beliakova, the Co-Director of JES - the outreach programme of the Institute of Mathematics of UZH and part of the Science Lab of the Faculty of Mathematics and Natural Sciences (MNF) of UZH.

Tatiana's research belongs to the interface of numerics, computational science and interdisciplinary research problems. She also has an additional research focus in mathematical education and applied didactics.

Puzzle Corner

1. Prisoners
The names of 100 prisoners are placed in 100 boxes. The boxes are lined up in a room.

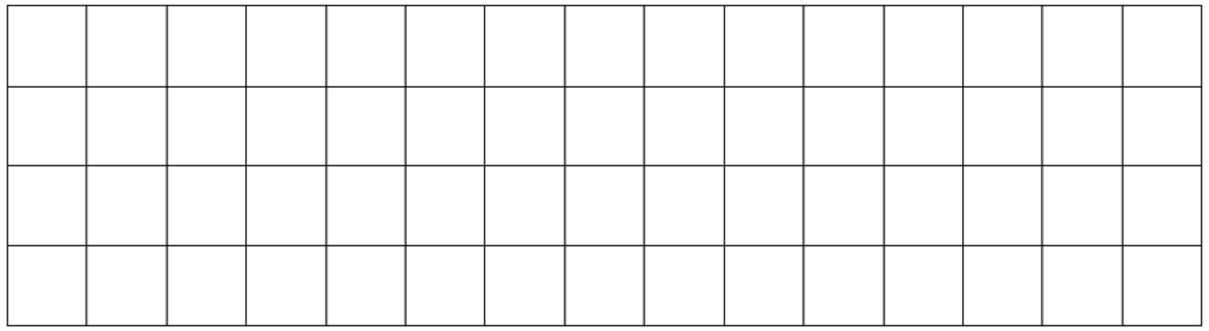
One by one, the prisoners enter the room. Each prisoner is allowed to inspect up to 50 boxes. Unless each single prisoner finds their name in a box, all will get executed. The prisoners can agree on a strategy before they start, but are not allowed to communicate afterwards. Do they have a strategy of surviving with probability greater than 30%?

2. The palindrome time
An electronic clock shows the hours and minutes. Leo looks at the clock and notices that the clock shows a palindrome time: The time looks like AB : BA. He decides to wait until it happens again. But after 4 hours he still did not see the next palindrome time.

How long does he have to wait?

3. Numbers on the blackboard
The numbers 1, 2 ... 2020 are on the board. What is the smallest amount of numbers that must be removed so that for any two remaining numbers a and b the sum a+b is not dividable by the difference a-b?

4. A hunt
A hunter and an invisible rabbit play the following game on an infinite square grid.



The hunter fixes a coloring of the squares of the grid in finitely many colors. The rabbit chooses a cell to start in. Every minute, the rabbit announces the color of its square and moves to an adjacent square that it has not visited before (two squares are adjacent if they share a side).

The hunter wins if either the rabbit does not have a possible move or the hunter can determine the exact location of the rabbit.

Does the hunter have a winning strategy?

Puzzle contributors:

No 1, 4: Kaloyan Slavov (ETHZ) | ETH Math Youth Academy | https://people.math.ethz.ch/~kslavov/

No 2, 3: Anna Beliakova (UZH) | TagesAnzeiger's - Test your math skills | https://www.tagesanzeiger.ch/ (Folge 223 des Zahlendrehers)

Answers

1. Prisoners
Yes. The prisoners can pick a bijection between the set of prisoners and the set of boxes. Once a prisoner enters the room, they look at the box corresponding to their own name. Then they open the box corresponding to the name found in that box and continue the process until they find their own name or until they have opened 50 boxes.

One can compute that the probability that a permutation of 1, ..., 100 has all cycles of length at most 50 is in fact more than 30%.

2. The palindrome time
Leo has to wait for 11 minutes.

3. Numbers on the blackboard
At least 1346 numbers must be removed.

Among three consecutive numbers x, x + 1, x + 2 one must not leave more than one, otherwise the pair (x, x + 1) will be dividable by 1 or the pair (x, x + 2) by 2.

So, from 2020 = 673 · 3 + 1, we must remove at least 673 · 2 = 1346 numbers.

We leave the numbers which, when divided by 3, give the remainder 1, i.e. 1, 4, 7, 10, . . . For each pair of such numbers, the difference is dividable by 3, and the sum is not dividable by 3.

So the sum cannot be dividable by the difference.

4. A hunt
The hunter has a winning strategy. For starters, observe that the following coloring (call it C_1)

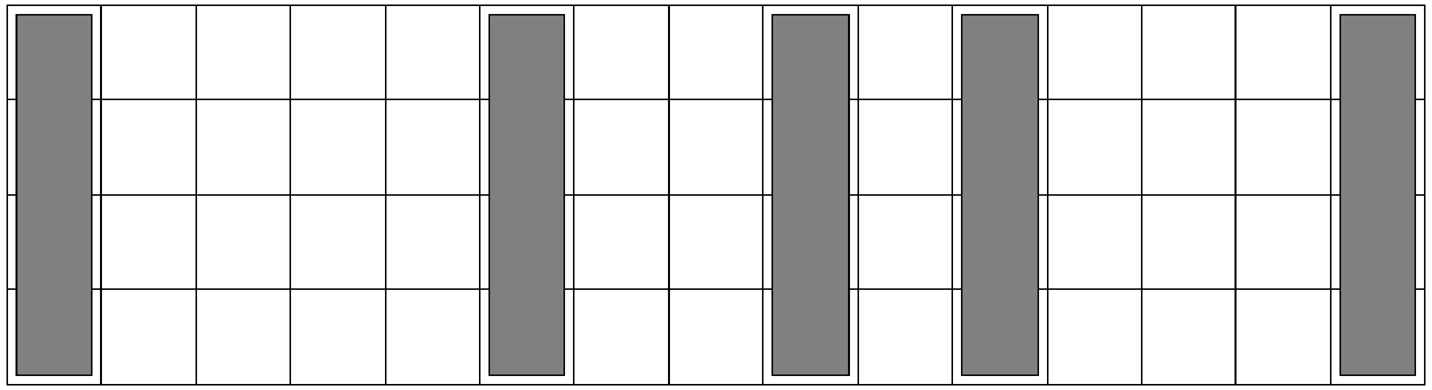
1	2	3	1	2	3	1	2	3	1	2	3	1
1	2	3	1	2	3	1	2	3	1	2	3	1
1	2	3	1	2	3	1	2	3	1	2	3	1
1	2	3	1	2	3	1	2	3	1	2	3	1

allows the hunter to detect whether a move is left, right, or vertical. A similar coloring C_2 of the grid in 3 colors but along rows would tell the hunter whether a move is up, down, or horizontal.

Observation. If $C_1,\ldots,C_k$ are finitely many colorings, one can form a coloring $C_1 \times \ldots \times C_k$ whose colors are tuples of colors from each of the colorings. This product coloring contains the full information that any of the C_i does.

In particular, the product $C_1 \times C_2$ allows the hunter to know whether a move is left, right, up, or down.

Next, consider a coloring C_3 of the columns in two colors (white and gray, say) such that the distances between the gray columns are pairwise distinct:



Suppose the hunter considers the coloring $C_1 \times C_2 \times C_3$. If the rabbit reports a second time that it is on a gray column, then using C_1 and C_2, the hunter can figure out which exact gray column that is. From that point on, the hunter will always know the rabbit's *x*-coordinate. Take a coloring C_4 in white and orange analogous to C_3 but along rows.

The hunter can consider the product of the above 4 colorings. If the set of *x*-coordinates and the set of *y*-coordinates of the rabbit are both infinite, then at some point the rabbit will visit a gray square for the second time and an orange square for the second time. Once that happens, the hunter will know the rabbit's location.

To address the possibility that the set of *x* or *y*-coordinates of the rabbit is finite, add a final coloring C_5 similar to C_3 and C_4 but along diagonals.

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