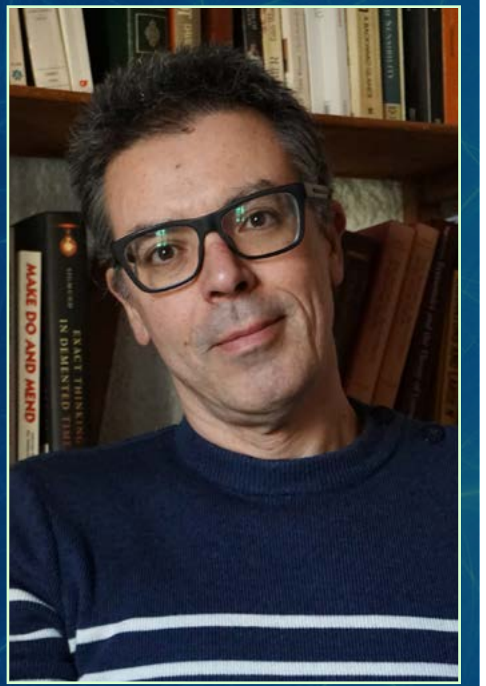
A conversation with Marcos Mariño



Marcos Mariño is a Professor of Mathematical Physics at the University of Geneva. He has a joint appointment in the Department of Mathematics and in the Department of Theoretical Physics.

He has held postdoctoral positions at Yale, Rutgers and Harvard, and he was a junior staff researcher at the CERN Theory Division.

His work focuses on the mathematical aspects of quantum field theory and string theory, and in particular on their interfaces with modern geometry and topology.

To be a mathematician or a physicist, how does one decide?
Well, being a mathematical physicist, you can say that I have not decided, because I do both. When I was young it was a difficult thing for me to decide between math and physics, until I realised that mathematical physics was a way of not having to decide. There are different types of mathematical physicists, some are closer to mathematics and some closer to physics. The type of mathematical physics I do is closer to physics. And indeed, I have a degree in physics, I do not have a degree in math. The mathematical aspects of my work are very important, but I consider myself more of a physicist.

When and how did you get interested in mathematical physics?
It happened very early in my life, and it was all due to outreach. My family comes from an artistic and literary background and there is no one else in my family doing science. But I was very influenced by a TV program by Carl Sagan called Cosmos. It was a series of documentaries about science in general and I was greatly impressed by a chapter where Carl Sagan explained special relativity. I was 11 or 12 years old at the time, and this completely converted me to science. I knew then that I wanted to be a physicist.

How did you choose the academic path?
I grew up in an intellectual environment where going into academia was a natural choice. For me, it was clear from the very beginning that I will study and do my PhD and continue on this path. If I wanted to be a scientist, that was the way to achieve it. So, once I decided to do physics and mathematics, the academic path was obvious.

Quanta magazine published an article about your work titled, "*How to Tame the Endless Infinities Hiding in the Heart of Particle Physics*".

What are you working on right now and what impact could your work have on the future?
One topic I am interested in is to understand some of the more formal aspects of quantum field theory. This is related to the topic of the Quanta article and the ERC Synergy Grant I got in 2018, together with Jorgen Andersen, Bertrand Eynard, and Maxim Kontsevich. In order to do calculations, one of the main tools we use in physics is perturbation theory. We know however that perturbation theory is not the final answer, and perturbative series need to be complemented with something else. The nature of this something else is a very interesting problem, since we do not know very precisely what it is. So, what I have been working on these past few years is to understand from a more mathematical point of view how to go beyond perturbative series in physics and also in mathematics, because perturbative series appear in mathematics as well.

I believe these are very fundamental questions. Quantum theory can be formulated in terms of the path integral invented by Feynman, which is supposed to give a mathematical description of quantum field theory, quantum mechanics, and string theory. But we don't really know what this object is. There are many mathematicians who have tried to describe it rigorously, but I have been using this different perspective based on perturbative series, which is sometimes called the theory of resurgence. One nice aspect of this perspective is that you find many interesting intermediary results. That is one of the important aspects of science: you usually have a long-term goal, but it is very important to get interesting partial results along the way, even if you don't reach your goal. And thankfully, we have been finding many of these.

My work is in a sense very experimental. You take an idea from physics and use mathematics as your laboratory.

In general, my approach to mathematical physics is different from other people within SwissMAP. The starting point in traditional mathematical physics is a physical theory that uses mathematics, but in a way which is not really rigorous. Then mathematical physicists use mathematical tools to make this physical theory rigorous. My approach is rather the opposite: I start from ideas and techniques in physics and try to see whether they can lead to new insights in mathematics. This was a very successful approach pioneered by Edward Witten, the famous physicist and fields medallist.

So one of my goals is to better understand the mathematical structure of quantum field theory and string theory, but I am also using ideas from these two areas of physics to better understand problems in geometry, topology, and algebra. This has led to surprising results that are not easy to obtain otherwise. I don't produce many theorems, I produce mainly conjectures, but conjectures are very important for the progress of science since they articulate research programs. They are also very useful to mathematicians because they can transform them into theorems. And quantum physics has turned out to be an incredible machine that produces many interesting conjectures.

What have been the most rewarding or favourite moments in your career so far?
Fortunately, there have been many rewarding moments in my career. When you do research, there are always great moments where things fall into place and you make a discovery, or something finally works. It is difficult to choose a specific one, but a good example is a problem I worked on when I was a postdoc of Greg Moore in the United States. Our first finding was that, according to quantum field theory, four-dimensional spaces have to satisfy some special properties or constraints. This was very surprising and no mathematician had suspected this, because this idea was coming directly from physics. After discovering this idea, we decided we wanted to test it. I spent some time collecting all the ways in which mathematicians have constructed four-dimensional spaces, and I tried to see if I was able to violate these constraints found with physics. This proved to be impossible: every day I would use a new technique from mathematics to construct four-dimensional spaces and try to see if I could evade these constraints. And every time I tried to evade them, I failed, and found that the constraints from physics hold true. This was a very rewarding result because it felt as though you found a new physical law for four-dimensional spaces. We then reformulated this law as a mathematical conjecture that was eventually proved by geometers who are experts in the field of four-dimensional topology.

So my work is in a sense very experimental. You take an idea from physics and use mathematics as your laboratory. You don't prove theorems, rather you make experiments with mathematical objects. And it is very satisfying when you find that your experiments work.

What have been the greatest challenges you had to face?
Of course, being a researcher is a permanent challenge. But I believe an important challenge in my life was related to my background. I did my bachelor and PhD in Galicia, Spain, which is where I grew up, but this is not the epicentre of the world in terms of research. And this puts one at a disadvantage. It is not the same thing to get your PhD in Princeton than to get it at a second or third-rate university. In the latter case, you receive a worse education and have a worse professional network, because you are less connected to the important people in your field. It is a difficult challenge to overcome the limitations that come from your background, in order to make it to the top places where you can do good research.

So this was a structural challenge that I had to address. And I think that people do not talk enough about this. Where you grew up, and where you have done your studies or PhD, are important factors that have an enormous impact in your life. There was an article in Nature in 2022 that showed that 20% of the universities in the world produce professors for 80% of the universities. Most university professors have been educated in a very select group of universities, so if you have received your education in a peripheral university, it is simply *more difficult to get to the top. I am surprised that people dealing with diversity and inequality in academia don't even talk about this, which is a massive source of inequality in the initial conditions of academic careers.*

Life is not predetermined and I have essentially overcome this challenge, but it has had nevertheless some side effects for me. For example, there are some topics in which I received a very bad education, as the courses I took were not very good. Of course, you can study on your own afterwards, but it is important to get a good education from good teachers at the right moment in your life. The fact that I didn't get a very good education has been a handicap.

You have been involved in outreach activities. Can you share some examples, including challenges faced and how they were addressed?

What do you find most rewarding about outreach?
I have to say that my view of outreach has changed over the years, and my current view might be interesting for those who are involved in outreach activities. In the typical outreach activity, scientists give a talk about their research in a simplified way, mostly about current cutting-edge results. This is of course a very good thing to do, but it also has shortcomings. In a nutshell, what happens is that many of the people who go to outreach conferences about cutting-edge research – like black holes, string theory or cosmology – do not really know how science is done. Some of them believe in bogus pseudo-sciences and in all kinds of conspiracy theories. After a popular talk I gave on quantum geometry recently, a woman in the audience asked me if we can use quantum physics to explain homeopathy. We know that homeopathy is ruled out by elementary physics and chemistry, so this example shows that there is an unbalance between the sophistication of some of our outreach and the public, who in many cases is not sufficiently educated about science at the more basic level.

So I believe there should be more outreach focused on basic issues in science, such as how to reach a scientific conclusion, what are cognitive biases, why some things cannot be trusted since they violate the basic principles of science, why pseudo-sciences which are popular do not really make sense, and so on. This type of scientific education would be very important in order to develop critical thinking in our society.

Concerning traditional outreach, I think that transmitting and making an impact on others is the most rewarding aspect. As I explained before, my scientific career is the result of outreach and popular science. There were no scientists in my family, so if it weren't for people doing outreach, maybe I would have become a philosopher or a philologist. But thanks to outreach, I became a mathematical physicist.

That is what is so rewarding about outreach – you can change people's lives. And even when you don't change their lives, you expose them to great ideas and their lives get richer. This is by the way also true for scientists themselves, since for me one of the best things about being a scientist is to be in a permanent and intimate dialogue with the scientific tradition.

What advice would you give to a PhD student who wants to pursue an academic path?
Academia has changed a lot since I started my studies. There is less faith in the search for truth and in the scientific method, and even within academia there are some tendencies that try to undermine the traditional way of doing science, which for me is still the right way to go. And this worries me a lot. So the advice I would give to a PhD student, or a beginning researcher, would be a traditional one: you have to work very hard. The PhD period is a moment in life where you are in front of a set of problems that you are supposed to solve, and it is crucial to solve them. Some of these problems might be hard, so this might be a very frustrating period as well, and people should be well aware of that. Failure is one of the possible outcomes, and it is not a good idea to try to find excuses when you don't solve a problem, you have to be prepared in case this happens. At least in mathematics and theoretical physics this is a period in your life where you are mostly on your own. Of course, you have your supervisors, but essentially you have to face this challenge by yourself.

I have the feeling that people are finding more and more excuses for not being able to address these challenges, and this is worrisome. External factors play a role, as I was pointing out before, but one cannot blame everything on them. At some point, it's just you and your problem. In an interview in 2021, the French physicist Édouard Brézin put this in a very clear way, and he says that once you have the material conditions to devote your entire time to solving a problem, the limitations are essentially your own. It is also going to be a difficult task, and very different from working a normal 9 to 5 job. It is something that will take over your life. And there is no way to sugarcoat it, it will be tough. Sometimes it will be very exciting and you're going to be incredibly happy when you solve a problem. And sometimes you're going to be in despair and feel sad and depressed. But that's all part of the experience. Research cannot be transformed into a "safe space" where nothing bad happens. It is more like a roller coaster, with ups and downs.

It is remarkable how people from different universities, and different regions, have come together through SwissMAP. It has created a sense of unity and a place for great communication and exchange of scientific questions and strategies.

What impact do you think SwissMAP has had on the scientific community?
SwissMAP has created a coherent and diverse mathematical physics community in Switzerland that would probably not exist in the same way otherwise. It is remarkable how all the people from different universities, and different regions, have come together through SwissMAP. It has created a sense of unity and a place for great communication and exchange of scientific questions and strategies. This is really impressive. I also believe that this community has made an impact on the rest of the world because the world has been impressed by this community which is very diverse but at the same time able to work together.

There is also the beautiful legacy that SwissMAP will leave behind in the form of the SwissMAP Research Station. It has become one of the most precious research stations in the world for mathematics and physics. I would like to take this opportunity to congratulate the people within SwissMAP who have worked hard to make this possible. They did an amazing job.

It is well known that you love movies and know a lot about them. You were also involved with the Ciné-club Universitaire.

What is it exactly about cinematography that you like so much?
I love cinema, but I also love literature and I am interested in many other things. This might not be very good for a researcher, as it distracts you from your work, but you only have one life and there are so many interesting things to discover. Cinema and literature have always been very important to me. In a sense, this is the legacy of my upbringing, as I grew up in a very literary and artistic family. My father also worked at the ciné-club of my hometown when he was a university student.

George Eliot, an English writer from the 19th century and an extraordinary woman, gave a very good answer to what is interesting about literature, cinema and the arts. She wrote that "Art is the nearest thing to life; it is a mode of amplifying experience beyond the bounds of our personal lot". This ability to enlarge your horizons and your experience is to me the most fascinating thing about literature and cinema. Note however that artistic form is crucial in this endeavour. In that sense, art is not very different from physics to me, since physical theories talk about experience, but I only really admire them when they are formulated in a precise and deep mathematical form.

Working at the Ciné-club Universitaire was a great thing, since it allowed me to meet film directors and critics and to organise events. Although I'm no longer involved in the Cine-Club, I am planning to organise a course on cinema and science in the University of Geneva for the academic year 2025-2026. I will try to put these two subjects together and see what happens. The idea is to teach cinema to scientists, and at the same time, to teach some science to students in the humanities. It will be a double challenge because you have to address both audiences.

In regards to literature, what is your favourite genre and what are you currently reading?
I don't have a specific favourite genre but I mostly read classics. Currently, I'm very interested in 19th century English and American literature, specially George Eliot, Henry James and Edith Wharton, who are among my favourite writers. I don't read a lot of contemporary literature. Being a scientist, however, I have been interested in science fiction, especially Philip K. Dick, Stanislaw Lem and the Strugatsky brothers. I also try to avoid reading in translation and focus on books written in languages that I can read (Spanish, Portuguese, French and English), although I have read a lot of German and Russian literature in translation for example. At this moment I have just finished "Wise Blood" by Flannery O'Connor, who was a female writer from the United States. This is a short novel that inspired a John Huston movie of the same title.

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