European Mathematical Society Magazine

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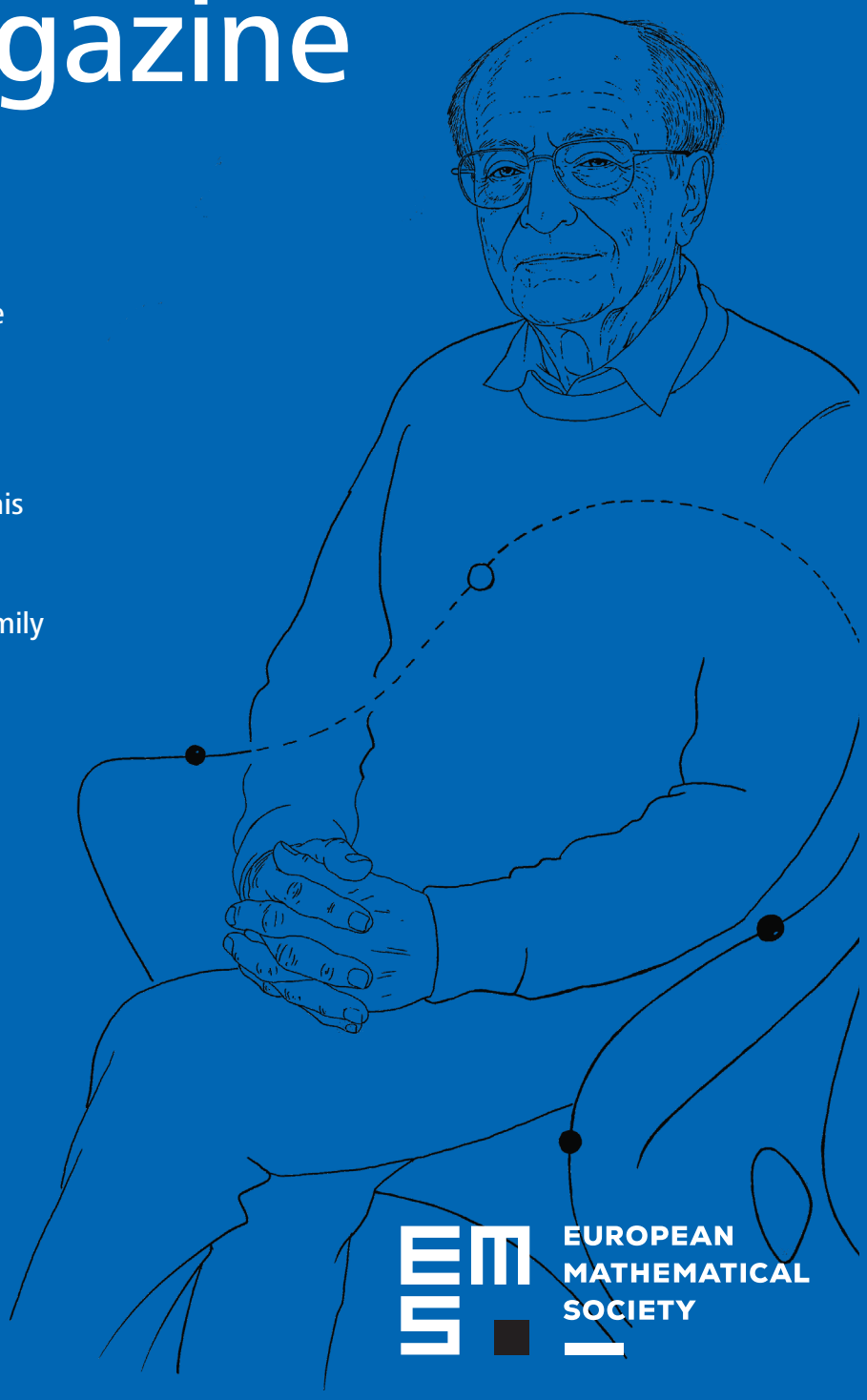
# EMS Magazine



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The myths of scientific edition

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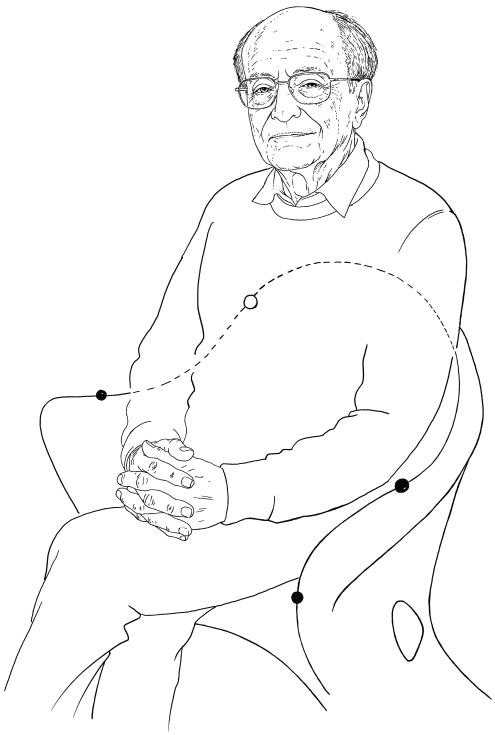

The cover is a portrait of Jean-Pierre Serre by A. B. Araújo, on the occasion of Serre's 100th birthday, which is commemorated in this issue.

# A message from the president

Photo by Jim Høyer, University of Copenhagen.

It has been a very intense summer period for the EMS and the worldwide mathematical community in general. At the end of June, we had the EMS council meeting. The council is the governing body of the EMS. The EMS's activities are being reviewed, and the budget suggested by the Executive Committee for the next two years is approved. The most exciting item on the council this time was the election of Professor Helge Holden as the new president of the EMS for the 2027–2030 period. Congratulations to Helge and to the EMS. Helge is well known to the EMS as he has previously served as the secretary of the society. He has also been secretary general of the IMU and until recently chair of the Abel Prize committee. It is wonderful news for the EMS to have such an experienced next president and also for me as outgoing president to know that I will leave the society in very good hands. I will work closely with Helge over the next few final months of my presidency to ensure a smooth transition. The council also elected Tuomo Kuusi as new treasurer replacing Samu Siltanen and Elena Celledoni as member at large of the Executive Committee. Adam Skalski who is already a member at large of the Executive Committee was elected as vice president replacing Jorge Buescu who will be retiring from the EC after having served there for many years. The new EC members will take on their positions from the beginning of 2027. It may be a little early, but I would still like to warmly welcome them to the EC. It is, however, too soon to say goodbye to the outgoing EC members. We still have work to do.

Immediately following the EMS council, we had a meeting of presidents. This is the opportunity for the EMS to engage with the presidents of our member societies and to discuss important issues. One item on the agenda that was proposed to us was the use of AI in evaluations, e.g., by funding agencies, and promotion and prize committees. The main questions were how funding agencies allow applicants and reviewers to use AI and how these policies are developing. Moreover, how are we going to evaluate research where AI plays an important and sometimes even decisive role. The discussion was kicked off by presentations from Kathryn Hess Bellwald representing the Swiss National Science Foundation, Maria Gonzalez representing the ERC, Olivia Mutham representing the Dutch NWO, and Frank Kiefer representing the German DFG. Finally, Alessio Figalli represented a personal view on the issues and challenges AI raise for promotions and prize committees.

The next item on the busy mathematics summer program was the General Assembly of the IMU in New York. A lot of important issues were being discussed and new officers elected for various committees. I presented the activities of the EMS. The most important news for mathematics in Europe was, however, the election of Glasgow as the venue of the 2030 ICM. The 2030 IMU General Assembly will be in Dublin, so this will be a two-country (Ireland/Scotland) event. The EMS had endorsed the Glasgow/Dublin bid as the only bid from Europe, and I want to congratulate them on winning. I wish them good luck with all the hard work in store over the next four years. I am sure it will be a very successful congress. The next four years will see two large congresses in Europe. First our own ECM in Bologna in 2028 and then the ICM in Glasgow in 2030.

After the IMU General Assembly the next stop was the ICM in Philadelphia and the announcement of the Fields Medals and the other IMU prizes. I congratulate all the prize winners. Prizes are of course a great honor for the recipients, but it is also, and maybe equally important, a great opportunity to celebrate mathematics at large. It was therefore particularly encouraging from the celebration perspective that all the prize lectures were exceptionally outstanding.

Not surprisingly there was again a lot of focus at the ICM on AI. Here it was mostly on AI as a tool for research mathematicians both as a means for proving new mathematical results but also in a broader context as a tool in conjugation with LEAN to support the formalization and verification of mathematics. There were of course both positive and negative perspectives on what this will all mean for the future of our profession. Whatever it will be there is no doubt it will have a major impact. As I already said in my previous message, I am probably more curious than worried about the future except for one aspect and that is the lack of equal opportunity and equal access to these new tools. Access may be restricted by who and where you are and by your financial means. Access to the best LLMs is exceedingly expensive for good reasons given the enormous power consumption. Access may also be restricted for political and security reasons. Here is an area where societies like the EMS can possibly play a role. We may not be able to secure equal access, but it is our duty to make sure the equal opportunity issue is addressed.

One of the panels at the ICM discussed the recent Leiden declaration on AI. While we did not formally endorse the declaration EMS issued a statement about it on August 5.[1]

[1] https://euromathsoc.org/news/leiden-declaration-on-artificial-intelligence-and-mathematics-224

I would like to take this opportunity to highlight a recent update to the ERC descriptors for applications to the mathematics panel. The updated list can be seen on page 39 of the document.[2] There are now 18 descriptors, the previous list had 22. I am proud to say that the EMS, through its EMS-ERC working group, engaged closely with the ERC to update and modernize the list. We plan to publish a more detailed article in a later issue of the Magazine about this.

This has already been a particularly long message but let me just mention that EMS has added the South African Mathematical Society (SAMS) and the Brazilian Mathematical Society to the list of societies with which we have reciprocity agreements. We have also signed Memoranda of Understanding (MoUs) with SAMS and UMALCA (Unión Matemática de América Latina y el Caribe).

Finally, I wish all of you a great start to the new academic year and happy 100th anniversary to Jean-Pierre Serre.

Jan Philip Solovej
President of the EMS

## Brief words from the editor-in-chief

Dear readers of the EMS Magazine,

After the summer break, I would like to begin this editorial by introducing the new editor who has joined the Editorial Board since the publication of our last issue: Raffaella Mulas. She will take care of the *Interviews and discussions* section of the Magazine. We already know her since she is conducting the interview series "Side by side."

A short biographical note of her can be found at the end of the issue. I thank Raffaella, and I am grateful to her for accepting to dedicate part of her time to our Magazine.

As the academic year begins again after the summer break, September brings with it a particularly remarkable anniversary: on September 15, Jean-Pierre Serre will celebrate his 100th birthday. His work, recognized by some of the highest distinctions in mathematics, has inspired generations of mathematicians and continues to shape contemporary research.

It is particularly appropriate to celebrate this milestone at the beginning of a new academic year. Universities and mathematical communities are once again filled with lectures, seminars, discussions etc. Serre's extraordinary career reminds us that mathematics is not only a body of knowledge, but a living body renewed through the exchange of ideas between generations.

For this reason, the September issue of the EMS Magazine is dedicated in part to celebrating Jean-Pierre Serre and his extraordinary contribution to mathematics.

Donatella Donatelli
Editor-in-chief

[2] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/guidance/information-for-applicants_he-erc-stg-cog_en.pdf

# An interview with Jean-Pierre Serre

Javier Fresán

*Jean-Pierre Serre will turn one hundred years old on 15 September 2026. On that occasion, a conference in his honour will be held at the Institut Henri Poincaré. When he suggests that I conduct what he calls "my first centenarian interview," my thoughts turn to Bernard Pivot's conversation with Marguerite Yourcenar at her home in Maine. "I had prepared that interview with the utmost care," Pivot recalls, "because I knew there was a risk of not rising to the occasion. Some writers are indulgent towards journalists and willingly accept questions that are less than compelling, but I knew that Marguerite Yourcenar, although very kind and welcoming, was not one of them. I could not afford to let her down."*

*The first part of the interview takes place on 19 April 2026, in Saint-Sulpice, where Serre now lives. Lac Léman is a three-minute walk away. On the train from Paris, I write each of my questions on a separate card. We talk without interruption for nearly five hours. He often gestures with his hands like a southerner. Towards the end of the interview, he chooses the next question at random by pointing to one of the cards.*

*I return to Saint-Sulpice the week of 6 July. I am there when he receives copies of the "fifth and last volume" of his collected works, containing most of his writings from 1998 to 2025. In the spirit of Bourbaki, we go through his answers together, reading them aloud line by line, pruning adverbs and adjectives, and "replacing false theorems with others."*

*Figure 1.* Serre at a restaurant in Feutersoey. (Photo by Eva Bayer-Fluckiger)

## Beginnings

Javier Fresán: *When did you realize that you were a mathematician?*

Jean-Pierre Serre: I realized that mathematics was what truly interested me when I was about sixteen. I was also interested in chemistry at the time, but I gave it up. As for becoming a professional mathematician, it took me a while to understand that you could earn a living as one. In those days, you could go straight from the École Normale Supérieure into the CNRS without having proved anything, simply on the strength of your potential. Well, I had ranked first in the *agrégation*, but that was purely pedagogic.

JF: *Ranked first despite your mishap at the oral exam …*

JPS: My first lecture was on lines on quadrics, a topic I knew well. I had even gone over it half-asleep the night before, so everything went perfectly. The second lecture was on prime numbers. I began by saying, "A prime number is …," and noticed that the examiners looked puzzled, but at the time they were not allowed to interrupt. When I was done, I suddenly thought, "Wait a minute, how did I define prime numbers?" I had managed to give the only incorrect definition one can think of: "A number is prime if it is divisible by neither 1 nor itself!"

JF: *That takes some doing!*

JPS: I have another story about the *agrégation*. The written exam was an analysis problem, based on an article by Marcel Riesz. I spent

*Figure 2.* Serre at his office, in 2026, with the *Éléments* by Bourbaki. (Photo by Javier Fresán)

about an hour trying to get from one equation to the next one. Riesz had probably written "by a change of variables," and given the formula, but the examiner (Jean Favard) thought that would be too easy for the candidates; he gave no hint on how to change variables.

After the exam, I came back to the École Normale. I went up to the first floor and passed a room where members of Bourbaki were discussing integration. I happened to arrive just as they were deciding to replace the language of $\sigma$-algebras with that of Radon measures (linear forms on the space of continuous functions). That really interested me, and that's why I later started attending Bourbaki meetings.

## Bourbaki

JF: *Was that your first contact with Bourbaki?*

JPS: I don't know how, but I found out that the next meeting was in Nancy in October 1948. At the time, I was living in Auxerre, because my wife was teaching there. Without telling anyone except her, I took the train to Paris, then another train to Nancy. I booked a room at a hotel, and the next day I went to the mathematics department. There was a large lecture hall where the Bourbaki meeting was taking place. I sat down at the back at first, then gradually moved closer and closer, and eventually I started taking part in the discussions. It didn't seem to bother anyone.

JF: *Who was there?*

JPS: Probably Cartan, Chevalley, Delsarte, Dieudonné … but what I remember most is something I said. They were discussing the chapters on field theory (*Algèbre V*), and Chevalley wanted to remove Galois theory because it's too technical. I intervened and declared, "Galois theory is useless." [I did not know that I would in fact use it for most of my life.] The Bourbaki members did not hold this childish sentence against me, and I was invited to the next meeting.

In the end, there was a compromise with Chevalley, who said, "If we include Galois theory in this chapter, then we should also do Lie algebras." Bourbaki agreed, and that's how the first report on Lie algebras by Chevalley came to be written.

Later, when Bourbaki invited me to join, I was asked to write something on ordered fields because I had published a short note on the subject. That's how I got started in Bourbaki.

JF: *Reading that first note on ordered fields, one has the impression that your style was already fully formed.*

JPS: That was the Bourbaki style. Did I learn to write by imitating it, or did that simply come naturally? I don't know.

JF: *Which texts did you write for Bourbaki?*

JPS: At the end of each meeting, Dieudonné assigned tasks to everyone, and for two years mine was to finish my thesis.

One text I spent a lot of time on was the *fascicule de résultats* on differentiable manifolds. That was difficult, because it gives only statements without proofs, so you have to work out the proofs in your head as you write. But at the time I was young enough to be confident, and I don't think I let anything incorrect slip through. I included many things that were not in the literature, for example, on foliations invariant under Frobenius on analytic varieties in characteristic $p$.

I also wrote a hundred pages of exercises (that were reduced to about forty by being set in small type) for one of the Lie volumes. I enjoyed it. For instance, I made up exercises on hyperbolic Coxeter groups, which I had learnt from Koszul's lectures at the Tata Institute, and also on Dickson invariants.

In commutative algebra, I had some influence on the programme. The old drafts used to start with "specializations," and I said: "No, we'll begin with flat modules." We kept valuation theory. Grothendieck, who was then a member of Bourbaki, thought that valuations were useless, but we kept them anyway.

## Grothendieck

JF: *Grothendieck had a complicated relationship with Bourbaki.*

JPS: He wasn't made for collaboration.

JF: *I have the feeling that you don't want to talk too much about Grothendieck, am I right?*

JPS: I have mixed feelings.

Few of the things Grothendieck did really surprised me. His early papers on nuclear spaces are very original. It's a theory I explained to Raoul Bott, and he was able to use it in one of his first papers. I was surprised by his Riemann–Roch theorem, because I had never seen statements of that kind over a general base. Étale topology did not surprise me, because I had found it in dimension one.

To me, the *Éléments de Géométrie Algébrique* were a display of great intellectual power, not of imagination. The work is more original than Bourbaki's, but the basic idea is still inspired by Bourbaki; there is a reason why it's called *Éléments*. Except for that, instead of a collective enterprise, it was the work of a single person. He himself used to say, "Once this is done, we'll be able to really do algebraic geometry." Indeed, these foundations have been widely accepted; they answered a real need. One of their good points is the choice of a suggestive terminology, such as "smooth" (lisse) instead of the ambiguous "regular," and "étale."

By that time, I no longer regarded algebraic geometry as a research topic for me, but simply as a working tool. I was drawn to number theory, algebraic groups, Galois representations, and modular forms. One cannot resist modular forms.

JF: *Grothendieck told you that modular forms were nonsense because of the artificial growth conditions at infinity, didn't he?*

JPS: He couldn't appreciate beautiful things that were not directly connected to what he was doing – the exact opposite of Weil's attitude. I tried several times to interest him in modular forms and, more generally, in the Langlands programme, but it was hopeless.

*Figure 3.* Serre and his father in the Cévennes, around 1928.
(Photo by Adèle Serre)

*Figure 4.* Serre and Merkurjev at the CIRM in 2015.
(Photo by Evgeny Plotkin)

## Influences

JF: *What influenced you most when you were young?*

JPS: One of the first serious books I read was the two-volume *Moderne Algebra* by van der Waerden. I had an uncle in America who became a millionaire from oil in Venezuela. His daughter, who was my age, managed to send me from New York books that were impossible to find in France in 1947: Banach's *Théorie des opérations linéaires*, Chevalley's *Theory of Lie Groups*, and van der Waerden's *Moderne Algebra*.

A Polish mathematician writing in French; a French mathematician writing in English; a Dutch mathematician writing in German. It was an excellent lesson: I shouldn't be afraid of foreign languages.

JF: *Are you an heir to the German school?*

JPS: Yes, in a sense. Mainly through my elders. Weil, Chevalley, and Dieudonné had gone to Germany to learn mathematics, because in France the main, indeed almost unique, subject at the time was functions of one complex variable.

I went on to read a great deal of German mathematics. As a student, I learnt more from *Moderne Algebra* than from Bourbaki. At that time, only the first version of *Algèbre: Chapitre I* existed.

The two books by Seifert and Threlfall were also important to me: *Lehrbuch der Topologie*, which covered the basics but also contained material that is still difficult to find today, and their volume on Morse theory, *Variationsrechnung im Grossen*.

Krull's *Idealtheorie* influenced me a little less because I was already working out commutative algebra on my own. It was clear that Krull understood the importance of localization.

JF: *Did you learn class field theory reading Artin?*

JPS: I first learnt it from Weil, sitting at a café near the rue d'Ulm. In less than an hour, he explained the theorems of class field theory to me in cohomological terms. It was a few years later that I read the Artin–Tate seminar. I could even attend part of it when I was visiting Princeton in January 1952.

JF: *What about Frobenius?*

JPS: I edited his *Gesammelte Abhandlungen* (Collected Works). That was a challenge because there was no complete list of his publications. I corresponded with Siegel, who had been a student of Frobenius and lent me many reprints of Frobenius's papers. I had to go through the major journals of his time, volume by volume, to see whether he had published there.

But I already knew Frobenius's results in group theory from standard textbooks. For example, I learnt character theory from *L'Intégration dans les groupes topologiques* by Weil.

I also like Schur's papers very much, but I only read them quite recently, in the last ten or twenty years.

## Group theory

JF: *Your most recent book is about finite groups, a subject you have been playing with for most of your mathematical life.*

JPS: I treated myself to an old man's pleasure.

I'm drawn to beautiful, concrete things. For instance, I wrote a whole chapter on "small groups," where I explain *with proofs* facts such as the isomorphism $\mathrm{PSL}_2(\mathbb{F}_9) \cong A_6$. Belief is easier than proof. People usually just say, "Take two elements; they generate the same subgroups …" But my Bourbakist moral is that I use explicit matrices as little as possible. I also enjoyed giving a proof of the well-known fact that, up to isomorphism, there is a unique simple group of order 168.

JF: *Is this your favourite book?*

JPS: No. My favourite remains *Lectures on $N_X(p)$*. Writing it was delightful.[1] Most statements concern schemes of finite type over $\mathbb{Z}$, with no extra assumptions. And then, because I had to explain the notation in the title, it was the only time when I did not have any trouble finding the first line of the introduction: "The title of these lectures requires an explanation …"

[1] AI told me that, among my books, this is the most difficult to read for students. I write for mathematicians, not for students.

*Figure 5.* Serre with Gross and Ribet during the conference *Applications of Automorphic Forms in Number Theory and Combinatorics* in 2014. (Photo by Bogdan Oporwoski)

JF: *It's rare to prove an interesting theorem about all groups, yet you've managed to prove one.*

JPS: That's what Humphreys wrote in his review of my paper dedicated to Borel. The main result is that, in characteristic $p$, the tensor product $V_1 \otimes V_2$ of semisimple representations of a group is semisimple, as long as the sum of the dimensions of $V_1$ and $V_2$ is at most $p + 1$.

When preparing my course at the Collège de France on torsion points of abelian varieties, I had seen results in this direction in Nori's work, but without a precise bound. Sometimes I ask myself questions because I can't resist finding out. I must have done some calculations and seen that $p + 1$ is a plausible bound. It is optimal for $\mathrm{SL}_2$, and Harish-Chandra had the philosophy that if you understand $\mathrm{SL}_2$, then you understand all semisimple groups. An optimistic point of view.

One day, Broué told me he was going to a conference in England, and he didn't know what to talk about. I told him, "You should mention this conjecture." I have no idea why I said that. When he left, I thought, "But why don't I prove it myself?" I did it. A strange experience …

## Happy doing mathematics

JF: *You always give the impression of being happy doing mathematics.*

JPS: Oh yes!

JF: *Were there moments of difficulty when you thought you were not going to make it?*

JPS: I was unhappy during my first two years at the CNRS because I wasn't finding anything except that note on ordered fields.

There was a difficult moment when I was a little over thirty. I had taken a road trip around the western United States with my wife and daughter. I spent a month figuring out which roads to take and looking for motels with swimming pools (for my daughter), and when I returned to the IAS, where I was a visitor, I couldn't work for another whole month.

I don't remember ever being unhappy after that. Showing that the Galois representation attached to an elliptic curve has large image took me roughly ten years, but I was doing other things in the meantime, and I wasn't unhappy because I was making progress.

JF: *Another article that was difficult to write was the one on modular representations of* $\mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q})$.

JPS: It appeared in 1987, but I had already mentioned a less precise form of the conjecture in a letter to Tate from 1973.

The case of level 1 was clear and fit the examples perfectly. Formulating a precise conjecture in the general case, thanks in particular to Mestre's numerical computations, took a long time. It required understanding the ramification of modular forms with "a nasty level and a bad character," a subject about which I learnt a lot from Fontaine.

I later realized that there are some cases in which the "precise form" of the conjecture is incorrect. The problem has to do with the notion of modular forms modulo $p$. I had chosen to view them as reductions modulo $p$ of the usual modular forms, a setting with which I was familiar and which could be explained easily. Yet, at a deeper level, I knew that they ought to be defined purely in characteristic $p$ terms, à la Katz.

JF: *That did not diminish your love for modular forms.*

JPS: I always loved playing in the "jardin des délices modulaires," as Godement called it. There are so many different points of view on modular forms that one of them is bound to give you something interesting. It's a perfect playground for optimists.

JF: *Have you ever attacked well-known open problems?*

JPS: Borel explained to me that if I am going to work on an open problem, one that other people have already struggled with, I have to feel that I've got something that others may have missed. That's why I have never tried to prove the Riemann hypothesis.

There are people whose minds are strong enough to focus on a single problem for a long stretch of time. Mine is not like that. It likes to play.

*Figure 6.* Serre and Fresán during the interview in April 2026. (Photo by Eva Bayer-Fluckiger)

## Homotopy groups of spheres

JF: *Cartan was your advisor, but he didn't give you a thesis problem. How did you find it?*

JPS: Cartan was my advisor in name only. I worked a great deal for his seminar, both learning things and writing them up. At first, I was interested in representation theory in infinite dimensions, but I couldn't find anything to do there. In the seminar, I learnt about homotopy groups and Eilenberg–MacLane spaces.

There is a striking duality between these two topics. In the case of spheres, homology is known and it is homotopy we want to determine. For Eilenberg–MacLane spaces, all but one of the homotopy groups are trivial, and we want to compute the cohomology. There are two different sides of the same topic. Whenever you make progress on one side, you make progress on the other.

JF: *Was that observation your starting point?*

JPS: No. I read a note a few lines long in which someone computed the cohomology of the Eilenberg–MacLane space $K(\mathbb{Z}, 2)$ by identifying it with infinite projective space $\mathbb{P}^\infty(\mathbb{C})$.

Since $\mathbb{P}^\infty(\mathbb{C})$ is the quotient $S^\infty/S^1$, and $S^\infty$ is contractible, we get a fibre bundle with contractible total space, base $K(\mathbb{Z}, 2)$, and fibre $K(\mathbb{Z}, 1)$. This suggested that, for an arbitrary abelian group $A$ and an integer $n$, there exists a fibration $E \to B$ with contractible space $E$ and base $B = K(A, n+1)$, which implies that its fibre $F$ is a $K(A, n)$-space.

I convinced myself that I could construct such a fibration by looking at the space $E$ of paths on $B$. More generally (as I noticed later), one may start with any connected space $X$, instead of $K(A, n+1)$, and define $E = EX$ as the space of paths, starting with

a given base point $x$ of $X$ (i.e., continuous maps $f\colon [0,1] \to X$ with $f(0) = x$, and define a projection map $p\colon EX \to X$ by $p(f) = f(1)$).

The fibre of $x$ is the loop space $\Omega X$ of $X$. Applying this construction to $X = K(A, n+1)$, one obtains what one wanted.

JF: *Was that the sudden discovery in the train compartment?*

JPS: Yes. I was on the night train coming back from vacation. I woke my wife and said, "That's it, I've got it!" I had found the fibration $E \to EX$ I wanted, except that none of the definitions of a fibre space in the literature at the time had been designed for this. But I was certain it would work.

Assuming also that I could use the Leray spectral sequence, I carried out many computations for Eilenberg–MacLane spaces and spheres. For Eilenberg–MacLane spaces with coefficients in $\mathbb{Q}$, I proved that the cohomology ring is a polynomial algebra. Dually, this suggested that the homotopy groups of spheres are finite.[2] At the time, people did not even know that they are finitely generated.

JF: *I guess you had to overcome technical difficulties.*

JPS: The main one was to show that Leray's spectral sequence applies to "my" fibre spaces, and especially to loop space fibrations. I was saved by Cartan and Koszul. At a Bourbaki meeting (around October 1950), they asked me where I stood with my thesis. Koszul suggested that I use cubes instead of simplices to construct a filtration. There were some annoying lemmas. I worked them out mentally for three days, lying on a sofa.

After three days, I could see them clearly enough to write down a proof. I could then write my thesis: at the pace of one page a day, seven days a week, it took me three months, and I defended it in May 1951. It appeared (in French) in the *Annals* at the end of the year.

Eilenberg had given me some good advice, as usual: "Don't try to go as far as possible. What you have is already very new."

JF: *Did you keep trying to compute more homotopy groups?*

JPS: For a while. One day, just after my thesis, I went to see Cartan and Eilenberg and told them that I had proved that the homotopy groups of spheres are effectively computable. They just laughed at me! So I decided to work on something else, and then a bit later someone published that result in the *Annals*. That is the only time Cartan laughed at me.

I went on computing the cohomology of Eilenberg–MacLane spaces with coefficients in $\mathbb{Z}/2$, and from this I was able to prove that for every $n \geq 2$, there exist infinity many integers $i$ such that the homotopy group $\pi_i(S^n)$, when finite, has even order.

JF: *So, in particular, it is non-zero!*

JPS: My interest in this kind of statement was sparked by a conversation with Chevalley. He told me the value of $\pi_i(S^3)$ for small values of $i$, which he had learnt from a lecture of J. C. Moore. I told him that I already knew them; I wanted to know more. He replied, "The other ones are zero."[3]

My little grey cells were outraged. "What? It's simply not possible!" ["C'est pas Dieu possible!"] So I proved the non-vanishing theorem quoted above out of indignation, an efficient technique. The proof made me use for the first time analytic number theory style arguments.

## Cartan

JF: *How were your relations with Cartan?*

JPS: There is a video in which Broué's daughter asks me, "What is Cartan to you?" I look at Cartan and say, "That's a little difficult to explain." He agrees: "Yes, it's a little difficult to explain." After that, we both laugh and I say: "At the École Normale, and in Sorbonne, I had professors who were not very good, and then Cartan came, and that was something else!" In the second volume of my collected works, I included a photograph of the two of us laughing like old accomplices.

We were like family: it was clear that I was a kind of son. After his death, I said in front of Cartan's family that "he was severe with mistakes, but not with the people who made them," and they all jumped because, in their experience, that was not true. I have no recollection of Cartan asking me to revise one of the texts I wrote for his seminar, whereas others had to produce two or three successive versions. He always accepted mine immediately. It seems I had the style he wanted.

Once he told me: "You see, Serre, in my day, you did your military service, wrote your thesis, got married, and had children. And you've done everything in the opposite order!" It was not quite true, because my daughter was conceived after I got married, but the rest was indeed in the opposite order.[4]

## Questions and conjectures

JF: *How do you tell a question from a conjecture?*

JPS: In principle, it's easy. A conjecture means that you think the answer is yes. A question means that you are not ready to commit yourself. For example, it used to annoy me that people called it

[2] With the exceptions of $\pi_n(S^n) = \mathbb{Z}$ and $\pi_{2n-1}(S^n)$ for even $n$, which is a direct sum of $\mathbb{Z}$ and a finite group.

[3] Of course, Moore had not said that; Chevalley had misunderstood.

[4] And, because I had a child, I avoided doing my military service.

*Figure 7.* Serre in Neuchâtel during an interview in April 2021 about his book *Rational Points on Curves over Finite Fields*.
(© Bureau presse et promotion, l'Université de Neuchâtel)

a conjecture – what later became a theorem – that projective modules of finite type over $k[x_1, \ldots, x_n]$ are free, because in FAC it was written explicitly: "It is not known whether …"

Once somebody published a paper in the *Annals* entitled *A counterexample to a conjecture of Serre,* a conjecture that I had never made. There again, I had written "It is not known whether …"

Later, Ekedahl and I published a note in *Comptes Rendus* about curves whose Jacobian is isogenous to a product of elliptic curves. We worked out a whole series of examples, some of pretty large genus, but we did not want to make conjectures. So instead we posed two questions: whether there are such examples for every genus $g$, or whether, on the contrary, only finitely many values of $g$ are possible.

JF: *You told me that you made your Conjectures I and II on Galois cohomology of algebraic groups "with a beginner's ignorance, but a taste for daring claims."*

JPS: I was very ignorant of algebraic groups at the time, but it all seemed so beautiful to me. As a former topologist I knew that $\pi_{n+1}(BG)$ is isomorphic to $\pi_n(G)$, so I was pleased with the idea of associating cohomological dimension 1 with connected groups ($\pi_0(G) = 0$) and cohomological dimension 2 with simply connected groups ($\pi_1(G) = 0$). I remember that Martin Kneser was skeptical about Conjecture II because he knew it was already difficult for classical groups over totally imaginary number fields. I didn't really know what had already been done and I didn't have any obvious counterexamples. I think I would not have made such a conjecture later on. I just got lucky.

JF: *Do you still think Conjecture II is true?*

JPS: Hard to say. I probably just don't think anything. In general, when I put forward a conjecture, I stop thinking about it. I consider that I've done my job, and then people can have fun with it. I'm not going to start solving my own conjectures …

JF: *Is there any of your conjectures where you regret not having been more daring?*

JPS: I always try to make the most daring conjectures, and sometimes they were too daring. Here's an example. In GAGA I had noticed that something was true for $\mathrm{SL}_n$ and symplectic groups. What do they have in common? They are simply connected! So I made a conjecture, and Grothendieck soon after proved that, on the contrary, it was true essentially only in those two cases. The conjecture was as false as possible.

JF: *Do you mind when one of your conjectures is false?*

JPS: No. There are people who take such things to heart, but I don't. I am delighted when a question is solved; be it with a yes or a no. I am surprised by people who think that it would be a catastrophe if the Hodge conjecture were false. It would be great progress! The important thing is to know.

It also irritates me when mathematicians write "unfortunately." Or that they "hope." It is absurd. When they are told that their hope is false, do they become hopeless?

It's not that things leave me indifferent, but counterexamples bring a lot of new information (think, for instance, of the Milnor–Kervaire constructions of spheres with non-standard differentiable structures – or with no such structure at all).

## Counterexamples

JF: *What is your favourite counterexample?*

JPS: I like my example of a smooth projective variety over a field $k$ of characteristic $p$ that cannot be lifted to characteristic zero. It was a counterexample to Weil's idea that one could always lift. He and Zariski thought they had a proof using the fact that Chow coordinates are defined by polynomial equations with coefficients in $\mathbb{Z}$ – which is correct but irrelevant.

When I told Weil, he wrote to me, "You have proved the Riemann hypothesis." That was his favourite way of saying that my argument was wrong, because from a false statement, anything follows. Later, he agreed that I had not "proved the Riemann hypothesis."

I was not completely satisfied with this counterexample. I wanted an example that is not liftable at all, meaning that if the variety lifts to a local ring $A$, then $pA = 0$. I was happy to construct such an example a few years ago, in a letter to Illusie that appears in the fifth volume of my collected works. One curious thing is that I need to assume that $k \neq \mathbb{F}_p$.

JF: *This "fifth and final volume," as you call it in the preface, has just appeared. What did you put in it?*

JPS: My favourite papers in this volume are:

(1) the paper on finite subgroups of $G(k)$, where I generalize Minkowski's bounds on the order of finite subgroups of $\mathrm{GL}_n(\mathbb{Q})$ to arbitrary reductive groups $G$ over arbitrary fields $k$;

(2) the paper on self-dual normal bases of Galois extensions in characteristic 2, with the surprising feature that the existence of such a basis depends only on the Galois group;

(3) the Bourbaki seminar on complete reducibility, a subject I greatly enjoyed because of the simplicity of its statements once they are translated into the language of Tits buildings;

(4) the notes from a series of lectures on cohomological invariants (UCLA, 2001), written with the help of Skip Garibaldi.

There are other topics I enjoyed writing about. For instance, *How to use finite fields for problems concerning infinite fields*. The rest may be less interesting, but Weil once told me that Collected Papers should include everything the author wrote.[5] One never knows what may interest a future reader. I regret that I did not always follow his advice. In the first four volumes of my *Collected Works*, I left out most of my joint papers with Borel, and now it looks as though I never worked on semisimple groups!

## Collaboration

JF: *Did you enjoy collaborating?*

JPS: I prefer writing alone, but I learnt a lot from collaborating, especially with Armand Borel. For our first paper together, on the subgroups of compact Lie groups, we worked Bourbaki style: one of us wrote a draft, and the other rewrote it entirely. But later on, we became lazy and used the dangerous[6] method of writing one section each and sticking them together.

With Hochschild, I used another Bourbaki method: reading our paper aloud one line by line. Yet we still missed an error in one of the theorems.

JF: *And besides writing?*

JPS: I like discussing mathematics, but I don't have many memories of proving something with other people. Here's an exception. I remember working with Borel on Sunday, 25 June 1950. We were in the hotel room in the Latin Quarter where my wife and I were living at the time. She came back at the moment we were finishing writing a note with the proof that you cannot fibre $\mathbb{R}^n$ by compact fibres not reduced to a point, and told us that the Korean War had started. We replied, "Oh really?," and simply went on with our work. That was my training in spectral sequences. We found the theorem on a Sunday, Cartan's father brought it to the Académie des sciences on Monday, and by Wednesday we had the galley proofs.

JF: *A few years later you also proved a theorem with Cartan during a Bourbaki meeting.*

JPS: It was about the finiteness of the cohomology groups of a compact analytic variety with coefficients in a coherent sheaf. I needed this for what I wanted to do with projective space. Cartan and I reduced the proof to a statement about perturbations of compact operators on a Fréchet space. It was clearly in Schwartz's expertise. We told him, "You prove that." Schwartz proved it. We told him, "You publish it." Schwartz said, "No, but I'm happy if you publish it." He gave us a draft of the proof; we wrote it as a note in *Comptes Rendus*, which was published under his name.

JF: *Among your contributions, do you have the feeling that some of them were less inevitable than others, that people might not have found them without you?*

JPS: In mathematics, one feels that everything would eventually have been done. It's rather the way things happen that is sometimes surprising. With the homotopy groups of spheres, the surprising ingredient was the loop space fibration. No such surprise in FAC, nor in GAGA.[7]

## FAC and GAGA

JF: *That's precisely a situation where the articles were not written in the order one imagines, right?*

JPS: I proved first that a coherent sheaf on complex projective space is given by a module over a polynomial algebra, and found the arguments of GAGA. But then I thought, "In this form, this should work over an arbitrary field, provided that one has defined coherent sheaves." So I had to write FAC before GAGA.

Everything was pretty obvious, except for a difficulty concerning cohomology. Standard definitions did not apply, and I had to define cohomology using coverings. But then Igusa wrote me that he was having a seminar on my work, and he couldn't prove the exact sequence of cohomology associated with an exact sequence of sheaves in degree $> 1$. I found a way out, using the part up to

[5] I kept his advice in mind when I edited the works of Frobenius, Cartan, Steinberg, and Tate.

[6] As the saying goes, "In collaboration, theorems add up and errors multiply."

[7] I coined those acronyms myself. They go so well together!

degree 1 to handle the case of affine varieties, and then affine coverings for the projective case.

A year later, Godement found the method of embedding a sheaf into an injective one, which allows for a definition where the cohomology exact sequence is obvious. That's the way Grothendieck did it later.

JF: *Where did the motivation come from?*

JPS: I wanted to know the analogue of Cartan's Theorems A and B on complex projective space. There are not enough holomorphic functions, but homogeneous polynomials take their place.

JF: *You were on the front line when Cartan proved Theorems A and B.*

JPS: Back from Princeton, I arrived to Cartan's seminar at the moment when he was explaining the two Cousin problems. Surprise. Cartan tells us that we should think of these problems in terms of sheaves (the subject of the previous year), that these sheaves are sheaves of modules over the sheaf of local rings, and that these modules are coherent (a new notion, inspired by Oka's work). Then he tells us that in the next lecture he will prove that the $H^1$ of such a sheaf on a Stein manifold vanishes. He also tells us that perhaps this can be generalized to higher degree. I jumped up to the blackboard and said to Cartan: "Yes, you absolutely must do the case of higher degree." Bruhat was by my side and supported me. I don't remember what Cartan replied to me, but the following week he had duly proved what became Theorems A and B.

JF: *Leaving topology was a decision?*

JPS: No. I never really changed subjects; there was always continuity. I kept topology as a tool and often used some of its ideas. For instance, once I was trying to prove a theorem about the cohomology of profinite groups. One starts with a profinite group $G$ and an open subgroup $H$ with finite $p$-cohomological dimension, and the question is whether the larger group $G$ has the same $p$-cohomological dimension. A necessary condition is that $G$ contains no element of order $p$. Is that enough? I was trying to construct a counterexample, but each time I ran into something that did not work. After a while, I realized that I was running into a question similar to the non-existence of certain maps between the cohomology of topological spaces. That non-existence followed from the properties of the Steenrod operations. What I had to do was clear: to use these operations in the cohomology of profinite groups. When I did, I had only to prove a few lemmas, and the matter was settled: no counterexample could exist. I was exhausted. That evening my wife offered me half a bottle of champagne. That's the only theorem which got me such a reward.

*Figure 8.* How to use an elbow crutch (Tel Aviv, 2000). (Photo courtesy of Jean-Pierre Serre)

JF: *Do you oscillate between trying to prove something and trying to construct counterexamples until one of them wins?*

JPS: Yes, I often do that. That's how Nagata proceeded when tackling problems in commutative algebra, where it is hard to have intuition: you try to construct counterexamples and see what prevents them from working. Also, Carleson spent two years looking for a function whose Fourier series does not converge almost everywhere to it, before proving that they do converge. After all, to prove a theorem is to prove that there do not exist counterexamples.

## Weil

JF: *I feel Weil is underappreciated (in French: "il n'est pas reconnu à sa juste valeur").*

JPS: I agree. Note that the French sentence "pas reconnu à sa juste valeur" is ambiguous. It only says that two things are different: no inequality sign.

JF: *What are your memories of Weil's 1948 course on his proof of the Riemann hypothesis for curves over finite fields?*

JPS: Except for conics, which I knew well, I had never heard of algebraic geometry. I attended the course and took notes, but did not understand much.

JF: *What was his lecturing style?*

JPS: He didn't write notes the way mathematicians usually do, but rather cards, in literary style. On one card there could be just a formula, without any proof. Then at the blackboard he would reconstruct the proof, with varying degrees of success.

I remember he once gave a talk at a conference in Japan where he went to the blackboard, wrote $L(s,\chi)$, and nothing else, for an hour. He went on and on about the beautiful properties of $L$-functions. That was the opposite of his writings, where there often is an entire page without a single line break.

Weil's natural place in Paris would have been at the Collège de France. Sometimes I dream of what it would have been like.

JF: *Why didn't they choose him?*

JPS: It was after the war, and they chose Leray. Leray had been a prisoner of war, whereas Weil had refused to serve.

## L'avenir des mathématiques

JF: *There was a time when you read and reread Weil's text* L'avenir des mathématiques*, from 1947.*

JPS: Oh yes! But I was shocked that my friends from Harvard didn't appreciate it. They did not realize at which date it was written and how prophetic it was. For instance, the sentence about studying the tower of extensions of a field obtained by extracting roots of unity of "infinitely increasing" order. That's exactly what Iwasawa did ten years later! This text is a marvel. No other mathematician wrote something at that level.

I think what Tate didn't like was the sentence, "For until now, however broad our generalizations of Gauss's results may have been, we cannot say that we have really gone beyond them." Are $L$-functions of representations of non-abelian groups to be regarded as a broad generalization of Gauss's results? Somehow I feel that Weil's claim from 1947 stopped being true when Langlands announced his programme, in a long letter to Weil in 1967 which circulated very quickly.

I can't believe that's a coincidence. Langlands had perhaps not read *L'avenir des mathématiques*, but he knew that Weil was the best person to understand him. If Langlands had never existed and Weil had been twenty years younger – there are a lot of "ifs" here – he might have been the one to discover the Langlands programme. Building bridges between different topics was his forte.

*Figure 9.* Serre and Fresán on 19 April 2026.
(Photo by Eva Bayer-Fluckiger)

JF: *In that respect, he was the opposite of Chevalley, right?*

JPS: Chevalley was in favour of working on one, and only one, topic at a time. Once he told me: "If one tries to put two different things into the same photograph, the result is blurred." A beautiful comparison, but "comparaison n'est pas raison."

For instance, he worked both on algebraic linear groups and number theory, but never on rational points of algebraic groups. He also succeeded in eliminating analytic methods from class field theory. As I said once,[8] "elles se sont bien vengées!"

## Langlands programme

JF: *How did you react to the Langlands programme?*

JPS: I already knew the implications for elliptic curves over the rational numbers (the modularity conjecture). What surprised me was the generality of Langlands's ideas. For example, the principle of functoriality, that you could transfer from one group to another. I was impressed that this could be done.

It's a programme, not a collection of conjectures that can be refuted with counterexamples. And because it's a programme, with many possible variants, it keeps moving forward. One of its charms is that it can be broken down into small pieces, and from time to time people manage to prove one of them. For example, Wiles

[8] In my lecture for the Galois bicentennial, thinking of the Langlands programme. The video is available at https://www.youtube.com/watch?v=zd0iIVPB8Qo.

proved one "small piece," about elliptic curves over $\mathbb{Q}$, and that small piece was enough to solve Fermat.

The development of the Langlands programme is the most important thing I have witnessed.

JF: *Langlands wrote his letter to Weil in 1967, the same year in which Weil published his paper "…* Funktionalgleichungen*" and Grothendieck gave a series of lectures about motives.*

JPS: 1967 was a great time for number theory, Grothendieck's motives, Langlands programme, Baker's effective bounds … I once gave a lecture[9] with that title.

Motives appeared in a letter that Grothendieck sent me in 1964, but they were not made public until 1967, in a seminar he gave at the IHÉS and that was never written up.

Motives didn't surprise me because I had often explained to him that the $\ell$-adic invariants associated with a morphism of algebraic varieties are related by the actions of Frobenius elements. Grothendieck took the idea much further. With his natural optimism, he decided that all morphisms between motives come from algebraic cycles, which is only reasonable assuming the Hodge conjecture.[10]

## Étale cohomology

JF: *A few years after Weil published his conjectures, you made an attempt to construct a cohomology theory for algebraic varieties in positive characteristic.*

JPS: It did not work. We already had cohomologies modulo $p$, but we didn't want to count fixed points modulo $p$. As an heir to the German school, I defined modules over the Witt vectors of the base field starting from the structure sheaf. In my optimism, I thought they would be free of finite type. For curves this is true, and they give the same answer as the $\ell$-adic representations, but in higher dimension there are counterexamples, already for a product of two supersingular elliptic curves.

Grothendieck talks about "Serre's tentative paper" in his lecture at the ICM. People asked me, "Didn't that bother you?" Not at all: he was right.

JF: *How was étale cohomology discovered?*

JPS: I was familiar with Weil's paper on fibre spaces, which I had presented at the Bourbaki seminar before writing FAC. Weil's fibre spaces are, by definition, locally trivial for the Zariski topology, and sometimes that works well. But if $H$ is a connected subgroup of $\mathrm{SL}_n$, the $H$-principal bundle $\mathrm{SL}_n \to \mathrm{SL}_n/H$ is in general not Zariski locally trivial. When $H$ is $\mathrm{SO}_n$, Lang had explained to me that the existence of a rational section would contradict well-known properties of quadratic forms over function fields. My motivation to introduce a slight variant of what became étale topology was to make these bundles locally *isotrivial*, a weaker notion than locally trivial. To view this as incentive for a new "topology" was a brilliant idea of Grothendieck.

I can still see the Darboux lecture hall where I gave my talk at the Chevalley seminar in April 1958. I had defined what I viewed as the "true" $H^1$, giving it that name, and Grothendieck immediately told me that this was going to give a Weil cohomology in all degrees with which one could perhaps prove the Weil conjectures.

JF: *What prevented you from going further?*

JPS: I hadn't even made the effort because I had a wrong instinct. I was a topologist, so to define $H^2$ I would have had to look at $\pi_2$, and that was enough to block me. But Grothendieck did not care about homotopy groups. In his mind, everything could be expressed in terms of what he called "topology."

## Proof of the Weil conjectures

JF: *How did you learn about Deligne's 1974 proof of the Weil conjecture?*

JPS: I think I have already told that story in a previous interview. I was in a hospital room about to undergo surgery. I phoned Deligne and told him about the little things I had been working on. He patiently listened to me, and then he said, "You know, I think I have proved the Weil conjectures." He explained the idea, and I saw it was correct. To do something so important starting from such a simple idea, that doesn't happen very often! The next day, the Raynauds came to visit me in the hospital, and I told them the basic principle of the proof.

JF: *Later, you would even explain it to the King of Sweden …*

JPS: When Deligne received the Crafoord Prize, I was invited to speak at the award ceremony, in the presence of the King and Queen of Sweden. I was given the instructions that my remarks should last no more than five minutes, applause included (?).

I had prepared just one sentence. Before saying it, I explained that Deligne deserved the prize because he had proved a very important result and I added, tongue-in-cheek, "So I suppose

[9] At the Harvard mathematics department, on 28 April 2017, with the title *50 years ago: a great time for number theory*. The video is available at https://www.youtube.com/watch?v=hs0lRR99vPI.

[10] Hence people who do not want to assume that conjecture have to use a different definition of motives, that of Yves André.

*Figure 10.* Serre in Saint-Sulpice in 2020. (Photo by Eva Bayer-Fluckiger)

you expect me to explain the proof." The mathematicians in the audience smiled knowingly: of course, that was impossible. Then I uttered the sentence I had prepared: "I am going to try." I heard the audience gasp.

I went to the blackboard, drew a potato, and explained that lots of people had tried to cut it into slices, but it never worked, until Deligne realized that there could not be a nasty slice, because that would lead to a contradiction.

JF: *You also delivered the laudatio when he received an honorary doctorate in Paris in 1995.*

JPS: There I chose the style of a fairy tale and spoke of the magic garden, which everyone could admire from afar, but whose door was locked. And it was Deligne who had found the key and opened the door so that we could all enter.

## Cleaning up?

JF: *In French toilets there is a sign, "Please leave this place as clean as you found it when you entered." Once you wrote to Tate that you felt the same way about mathematics. Are there parts of your work that you didn't leave clean?*

JPS: There are at least two topics that I left "dirty."

The first is the sign problem in my duality theorem for coherent cohomology on a smooth projective variety $X$ of dimension $n$. The proof was carried out in two stages, separated by at least one year. I first proved, by induction on the dimension, that $H^n(X,\omega)$ is one-dimensional and that it is target of a non-degenerate pairing. This is sufficient for many applications, but not for all. For instance, it doesn't imply that automorphisms of $X$ act trivially on $H^n(X,\omega)$. It took me about a year to prove that $H^n(X,\omega)$ actually has a canonical element. Of course, that element had to be independent of the chosen projective embedding. The main point concerns signs.[11] Unfortunately, I did not publish my proof, because I thought it would follow from Grothendieck's more general results, and now I no longer remember the method.

The second example is the properties of the Galois groups associated with abelian varieties over a number field. I gave two courses at the Collège de France in 1984–1985 and 1985–1986. There are handwritten notes of the lectures available at Numdam, and letters to Ribet, Bertrand, and Vignéras explaining with proofs the main results, but a detailed account is lacking, probably because these results are themselves incomplete.

## Publishing

JF: *Have you ever had a paper rejected?*

JPS: Only once. My paper on the Euler–Poincaré distribution of a profinite group was rejected by *Inventiones*. Looking back, I agree it probably did not deserve to be published in such a good journal.

JF: *And how many times did you receive a referee report?*

JPS: Two or three times. There were no referee reports for FAC, GAGA, etc. In 1952, my paper with Hochschild on the cohomology of extensions of Lie algebras was refereed by Chevalley. He suggested that we use exterior algebra, and I refused on the grounds that everything works for infinite-dimensional Lie algebras as well. I think the next time was in 1984, when I submitted my paper on the Witt invariant of the form $\mathrm{Tr}(x^2)$ to *Commentarii*, and Kervaire found that the arguments at the end were too brief and should be expanded.

When I dedicated my paper "Galois is large" to Weil, he thanked me for "this mass celebrated in my honour" and made substantial suggestions. I considered each of them, but they would have required altering the carefully chosen order in which the material was presented. So I didn't change anything.

[11] A typical example: is the residue of the 2-form $dx\,dy/y$ at $y=0$ equal to $dx$ or to $-dx$?

## Collège de France

JF: *Where did you most enjoy doing mathematics?*

JPS: I do mathematics at home, not in an office.

As for lecturing, the places I like most are Harvard and the Collège de France. I also enjoyed the atmosphere at Princeton's Institute for Advanced Study and at the IHÉS.

JF: *You often gave the same course at Harvard and the Collège.*

JPS: Tate would write to me, "Do you want to come this year?" and it was understood that I would give a course. I usually chose something that I was going to talk about later at the Collège in more detail; it served as training. I chose the subject completely freely, of course. They were both wonderful audiences.

Only the first year at the Collège was difficult because I had a small audience, and that audience was Grothendieck, Cartan, and Cartier, and they asked me tons of questions during the lecture. When I got home, I was exhausted.

JF: *You stayed at the Collège de France for almost forty years. Were there times when it felt like a burden to have to give a course on new research every year?*

JPS: It was never a burden because I could take sabbatical years from time to time, and I did when necessary. In 1993, on the road back from climbing rocks in Fontainebleau's forest, I realized that I didn't have a topic for the following year, so I just decided: "I'm going to retire." I told my wife when I got home, then informed the Collège. I finished my course by saying, "This is my last course: not just of the year, but the very last one." When I tell this story, I like to add: "and they all threw themselves on the floor in despair." Too bad: no one did that.

JF: *Did you ever interact with other professors?*

JPS: Yes, with Jacques Tits. Not with the others. I went to listen to one of Foucault's lectures because he was an old friend from the École Normale Supérieure. The room was packed; there were lots of marginal characters sitting on the floor – it suited him very well – and he was reading from a text. So I asked Foucault, "Why do you do that?" And he replied something that shocked me: "The way I say things is more important than what I say." He did not want people to make a fuss about him using one term rather than another. I thought that was a bad sign.

## Old age

JF: *In* Souvenirs d'apprentissage*, Weil recalls that old people in India, when eating chili peppers, can no longer experience the intensity of the taste they remember from their youth. Are there any areas of mathematics for which you have lost the taste you had when you were young?*

JPS: I cannot think of any. It rather goes in the other direction. Getting older made me appreciate topics of which I was ignorant (or even did not like) when I was a beginner. A good example is analytic number theory, which I now like very much – especially because of its growing intersection with other topics such as Lie groups. I also like combinatorics.

## Outside of mathematics

JF: *Let's finish by talking about something else. Outside of mathematics, what interests you the most?*

JPS: What do I like most? Books, movies, sports come to my mind:

(1) Books. So many! Here are some names of books and authors I like most:

Jean Giono's books of the post-war period (*Les récits de la demi-brigade*, etc.).

That irresistible Jewish writer, Isaac Bashevis Singer.

Nabokov's *Ada* is a marvel. It even played a small role in the International Mathematical Union. I was vice-president, and the other vice-president was Faddeev. When the question arose of choosing the next president, I didn't want the job, so I campaigned for Faddeev. It was the first time a Russian had been chosen, and this was during the communist period. And why did Faddeev and I get along so well? Because the two of us loved *Ada*, and that created a bond.

I also like the Japanese: Ishiguro, Murakami …

I read Proust during my first visit to Japan for the Tokyo–Nikko conference in 1955. I stayed there for almost a month, in an environment where the only languages spoken were Japanese and English. I had brought along a volume from the Pléiade edition, and in the evening, to relax, I would read passages from it. I love the third volume, *Le Temps retrouvé*. I like the first two less. "Longtemps, je me suis couché de bonne heure." It is splendid to begin a thousand-page book with such a short sentence. Bourbaki sometimes made fun of me because I had a tendency to begin a write-up with the short sentence, "Let $n$ be a positive integer."

From Thomas Mann, I like *Joseph and His Brothers* and *Der Erwählte*. There is also *Lotte in Weimar*, which amuses me because there is a chapter in which Thomas Mann puts himself inside Goethe's mind, half-asleep. It's a bold thing to do for a German

*Figure 11.* Serre with his nephew Denis and his grandniece Margaux at Fontainebleau on 16 September 2024. (Photo by Jean-Paul Crosefinte)

writer, as scandalous as if a mathematician wrote "I am going to put myself into Gauss's mind."

Among more recent books, *Le bâtard de Nazareth* by Arditi.

(2) Movies ("le septième art"). I especially like those of Studio Ghibli (*Howl's Moving Castle*, *Kiki's Delivery Service* …), the Coen brothers (*O Brother*, *Where Art Thou?*, *Fargo*, *No Country for Old Men*), Tarantino (*Pulp Fiction*, *Django Unchained*), Woody Allen (*Mighty Aphrodite*), Altman (*McCabe & Mrs. Miller*), Pabst (*Die Dreigroschenoper*), Hitchcock (*The Trouble with Harry*) …

(3) Sports. My favourite were table tennis and rock climbing. I stopped the first one when I was 70 or so; I kept rock climbing (Fontainebleau boulders, and also Chamonix training cliff "Les Gaillands") until I was about 95; I had to stop because the muscles were just gone. But I still enjoy going to Fontainebleau with friends or family, and revisiting the rocks I used to climb.

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# From equations to coastal hazard assessment: mathematical modelling of tsunamis

Carlos Sánchez-Linares

*Mathematical models play a central role in the understanding and prediction of tsunami hazards. Over the last decades, advances in numerical methods, high-performance computing and geospatial data have enabled the development of operational simulation tools capable of supporting early warning and risk assessment activities. In this article we discuss the mathematical foundations of tsunami modelling and describe how these models have evolved into operational systems used in real-world applications, including the Copernicus Emergency Management Service (Copernicus EMS).*

## 1 Introduction

When a tsunami crosses the open ocean, it travels at the speed of a commercial aircraft. Yet far from the coast it may pass almost unnoticed: the wavelength of the wave can reach hundreds of kilometres while its height is often only a few tens of centimetres. Only when the wave approaches shallow coastal waters does this enormous amount of energy become visible, transforming into the destructive surges that have shaped the history of many coastal regions [11].

Behind this dramatic physical phenomenon lies a surprisingly compact mathematical description. Although tsunamis involve processes that extend across entire ocean basins, much of their large-scale behaviour can be captured by depth-averaged models derived from the shallow water equations [6, 10]. These equations describe how gravity, fluid motion and the geometry of the seabed interact to produce waves capable of travelling thousands of kilometres from their source.

Describing the phenomenon mathematically, however, is only the first step. Turning these equations into practical tools requires numerical methods capable of solving them efficiently over domains that range from deep ocean basins to complex coastal environments. This multi-scale nature of the problem poses a significant challenge: simulations must cover very large regions while still resolving coastal processes that may occur on the scale of tens of meters [7].

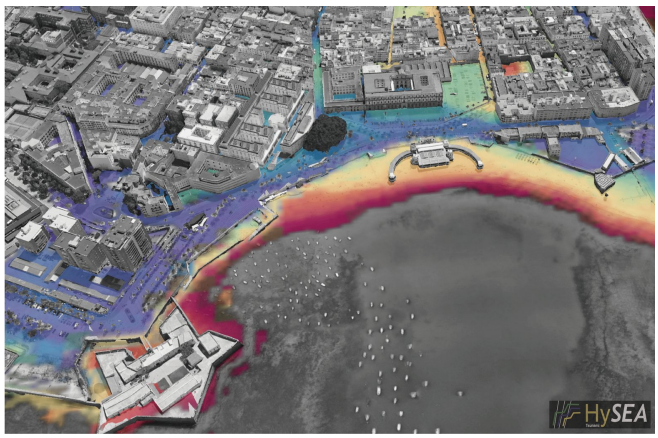


*Figure 1.* High-resolution tsunami inundation simulation in Cádiz (Spain), showing the interaction between the incoming wave and the urban environment. (Base imagery © Google Earth, Landsat/Copernicus)

Over the past decades, advances in numerical methods, high-performance computing and geospatial data have transformed tsunami modelling into a powerful framework for hazard assessment. Numerical simulations are now routinely used to reconstruct historical events, explore hypothetical earthquake scenarios and estimate potential inundation in coastal regions [12, 13]. In many cases these models must produce reliable results within minutes after an earthquake is detected, forming part of the computational infrastructure of tsunami early warning systems [3].

The work described in this article lies at the intersection of these developments. Over the years, a family of numerical models known as HySEA has been developed with the aim of combining robust mathematical formulations with highly efficient computational implementations [8]. These models have been applied to problems ranging from tsunami propagation and coastal inundation to other types of geophysical flows.

Rather than focusing on technical details, our aim here is to illustrate how mathematical modelling and numerical simulation can evolve from theoretical ideas into practical tools that support

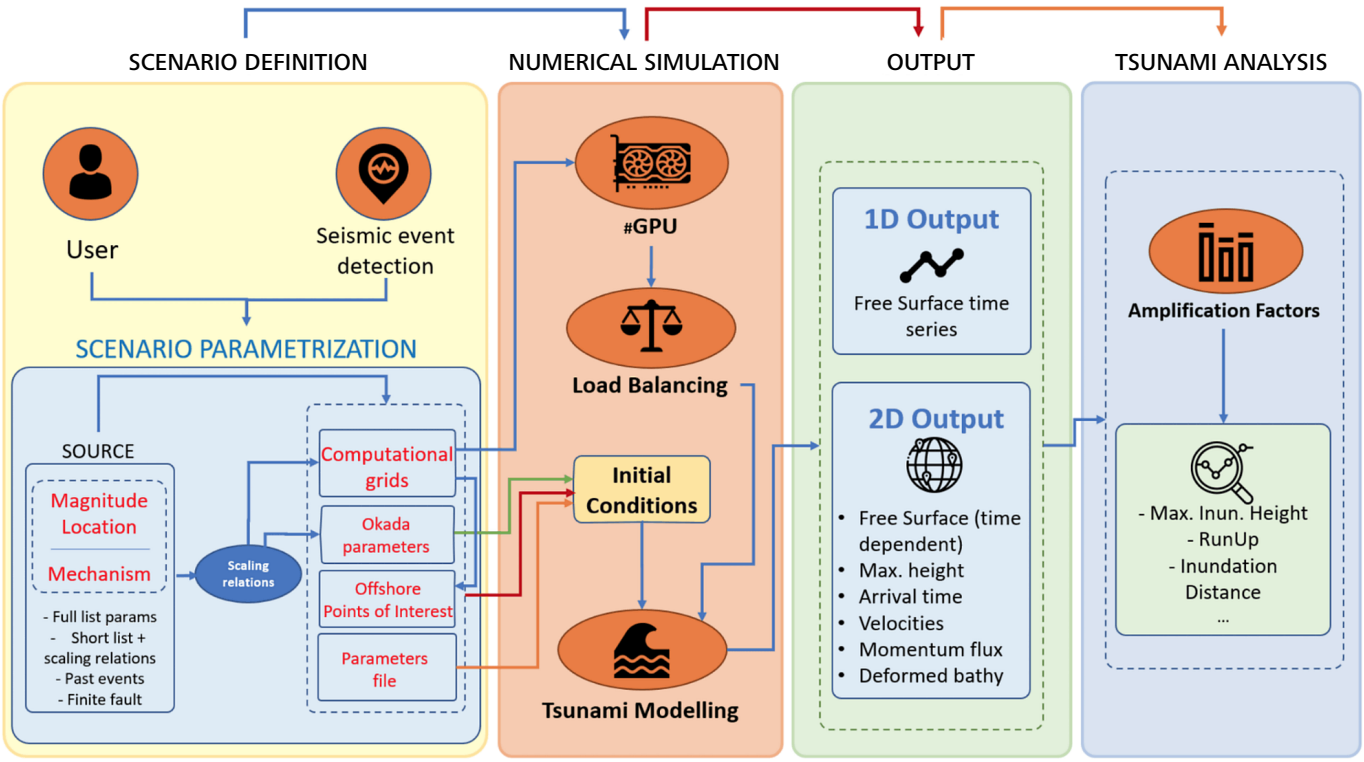


*Figure 2.* Schematic workflow of tsunami simulation, from scenario definition and source parametrisation to numerical simulation and hazard analysis.

hazard assessment, emergency preparedness and long-term planning in coastal regions.

Before describing the mathematical models and numerical methods in detail, it is useful to outline the typical workflow followed in tsunami simulation and hazard assessment studies.

Starting from the detection or definition of a seismic event, the process involves several stages, including the parametrisation of the source, the construction of suitable computational grids, the numerical simulation of wave propagation and inundation, and the post-processing of the results to extract relevant hazard indicators.

This workflow is summarised in Figure 2, which illustrates how mathematical models, numerical methods and computational tools are combined in practice to produce actionable information for risk assessment.

In the following sections we focus on the mathematical and numerical components of this workflow, and on how they can be translated into efficient computational tools for large-scale tsunami simulation.

## 2 Mathematical and numerical models for tsunami waves

Tsunami propagation across ocean basins can be described with remarkable accuracy using depth-averaged models. The fundamental observation is that tsunami wavelengths are typically much larger than the local water depth. Under this assumption the vertical structure of the flow can be averaged and the dynamics of the water column can be represented by the shallow water equations, a system of hyperbolic balance laws widely used in geophysical fluid dynamics [6, 10].

These equations describe the evolution of the total water depth and the depth-averaged horizontal momentum under the influence of gravity and bathymetry. Despite their relatively compact mathematical form, they capture the essential mechanisms governing tsunami propagation, including long-distance wave travel, interaction with bottom topography and amplification near coastal regions.

### *2.1 The shallow water equations on the sphere*

For simulations at the scale of entire ocean basins it is natural to formulate the shallow water equations directly on the sphere using longitude-latitude coordinates. In this framework the unknowns are the total water depth $h$ and the depth-averaged momentum components $q_\theta = hu_\theta$ and $q_\varphi = hu_\varphi$, where $u_\theta$ and $u_\varphi$ denote the horizontal velocity components.

When modelling tsunami propagation across ocean basins, it is convenient to express the governing equations in spherical

coordinates $(\theta, \varphi)$ representing longitude and latitude. The resulting depth-averaged system governing the evolution of the water column is shown below.

$$
\begin{cases}
\partial_t h + \dfrac{1}{R\cos(\varphi)}\left(\partial_\theta q_\theta + \partial_\varphi(q_\varphi \cos(\varphi))\right) = 0, \\
\partial_t q_\theta + \dfrac{1}{R\cos(\varphi)}\partial_\theta\left(\dfrac{q_\theta^2}{h}\right) + \dfrac{1}{R}\partial_\varphi\left(\dfrac{q_\theta q_\varphi}{h}\right) \\
\qquad - 2\dfrac{q_\theta q_\varphi}{Rh}\tan(\varphi) + \dfrac{gh}{R\cos(\varphi)}\partial_\theta h = \dfrac{gh}{R\cos(\varphi)}\partial_\theta H, \\
\partial_t q_\varphi + \dfrac{1}{R\cos(\varphi)}\partial_\theta\left(\dfrac{q_\varphi q_\theta}{h}\right) \\
\qquad + \dfrac{1}{R}\partial_\varphi\left(\dfrac{q_\varphi^2}{h}\right) + \dfrac{(q_\theta^2 - q_\varphi^2)}{hR}\tan(\varphi) + \dfrac{gh}{R}\partial_\varphi h = \dfrac{gh}{R}\partial_\varphi H.
\end{cases}
$$

Two–dimensional shallow water equations in spherical coordinates used for large-scale tsunami simulations.

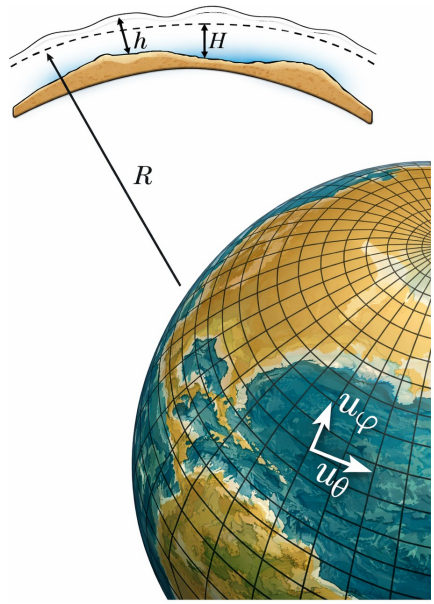


*Figure 3.* Schematic of the shallow water equations in spherical coordinates.

This system expresses the conservation of mass and momentum in a rotating spherical geometry. The terms involving the bathymetry $H$ account for the influence of the seabed on the flow, while the geometric terms arise from the curvature of the Earth and the use of spherical coordinates. Together, these contributions determine how tsunami waves propagate over large distances and interact with the underlying topography.

In tsunami applications, the system is typically complemented with initial conditions representing the deformation of the ocean surface generated by an earthquake.

These deformations are commonly computed using elastic dislocation models, most notably the formulation proposed by Okada [9]. This approach provides a practical way of linking seismic source parameters with the initial state of the hydrodynamic model.

While the governing equations have a relatively compact mathematical structure, their efficient solution over domains that may span entire ocean basins remains a significant challenge. This is due not only to the large spatial scales involved, but also to the need to accurately capture wave propagation across the ocean and its interaction with complex coastal environments.

### *2.2 Finite-volume discretisation*

The numerical solution of the shallow water system presents several difficulties. The equations are nonlinear and hyperbolic, and their solutions may develop steep gradients associated with propagating wave fronts. Realistic simulations must also handle highly variable bathymetry and the appearance or disappearance of water near the shoreline during inundation.

A further difficulty comes from the presence of bathymetric source terms. The equations are therefore not purely conservative, and the numerical method must preserve delicate balances between fluxes and topography. Finite-volume methods provide a natural framework for this task.

In this setting, the computational domain is divided into control volumes and the governing equations are integrated over each cell. Denoting by $U_i^n$ the average value of the conserved variables in cell $i$ at time $t^n$, the resulting update takes the form

$$U_i^{n+1} = U_i^n - \frac{\Delta t}{\Delta x}(F_{i+1/2} - F_{i-1/2}) + \Delta t S_i.$$

Here the interaction between neighbouring cells is represented through numerical fluxes across cell interfaces, as illustrated in Figure 2.

This formulation provides a robust basis for tsunami simulation over large domains. In particular, well-balanced discretisations are required so that equilibrium states corresponding to water at rest are preserved at the discrete level.

In this formulation the interaction between neighbouring cells occurs through numerical fluxes computed at their interfaces, as illustrated in Figure 4.

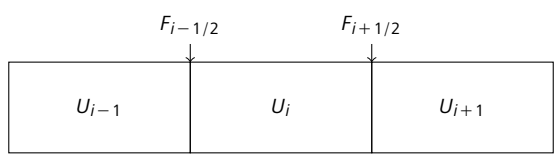


*Figure 4.* Finite-volume discretisation. The conserved quantities are represented by cell averages and evolve through numerical fluxes exchanged across cell interfaces.

This conservative formulation provides a natural framework for constructing robust numerical schemes capable of accurately propagating long waves across large computational domains. In practice, well-balanced discretisations are incorporated so that stationary solutions corresponding to water at rest are preserved at the discrete level.

### *2.3 High-resolution schemes for propagation and inundation*

Building upon this finite-volume framework, high-resolution numerical schemes are introduced in order to accurately capture steep wave fronts while avoiding spurious oscillations.

Within the HySEA framework, the numerical fluxes are computed with high-resolution finite-volume schemes designed to propagate steep wave fronts accurately while avoiding spurious oscillations. In smooth regions these methods achieve higher-order accuracy, while near sharp gradients they remain stable and robust. In particular, weighted average flux (WAF) formulations combined with total variation diminishing (TVD) limiters are employed to obtain stable and accurate approximations of the shallow water system [1].

In this approach piecewise linear reconstructions of the conserved variables are constructed inside each computational cell and slope limiters are introduced to control the total variation of the numerical solution. The resulting scheme achieves second-order accuracy in smooth regions of the flow while preventing spurious oscillations near steep gradients.

Additional numerical treatments are required in coastal areas in order to deal with inundation processes. In particular, wetting and drying techniques are incorporated to allow the numerical model to track the moving shoreline as the tsunami wave runs up over initially dry land.

By combining high-resolution propagation schemes with robust inundation treatments, the Tsunami-HySEA model provides a unified numerical framework capable of simulating both the propagation of tsunami waves and their complex interaction with coastal environments.

## 3 From mathematical models to operational tsunami simulation

The mathematical and numerical techniques described in the previous section provide the foundations for tsunami simulation. Transforming these models into tools capable of supporting real-world applications, however, requires addressing additional challenges related to data preparation, computational performance and large-scale simulation workflows.

A particularly illustrative example of this transition arises in tsunami hazard assessment studies carried out along the Spanish coastline within the framework of Copernicus EMS. In these applications, the Tsunami-HySEA model is used to simulate worst-case tsunami scenarios and to quantify their potential impact through high-resolution inundation modelling.

The objective is not only to reproduce wave propagation, but also to provide quantitative information on coastal flooding that can support risk assessment and decision-making processes. This requires the integration of geospatial data, physical models and high-performance numerical simulation into a coherent computational workflow.

The overall methodology followed in these studies can be interpreted as a structured pipeline. Starting from the definition of seismic source scenarios, the process includes the construction of consistent topobathymetric models, the generation of initial conditions through seafloor deformation models, and the simulation of tsunami propagation and coastal inundation using multi-resolution computational grids.

The resulting numerical solution is then post-processed to extract quantitative indicators of tsunami impact along the coastline. The different components of this workflow are described in the following subsections, emphasising their role within this hazard assessment framework.

### *3.1 Geospatial data for coastal hazard assessment*

In this workflow, particular attention is paid to the integration of large geospatial datasets describing both the ocean floor and the coastal terrain. In practice, this involves combining bathymetric information from marine surveys with high-resolution topographic data obtained from digital elevation models.

One of the main technical challenges is the construction of a consistent topobathymetric model that seamlessly connects underwater bathymetry with onshore topography. Small inconsistencies in the data, particularly near the shoreline, may introduce numerical artefacts that significantly affect inundation simulations. Considerable effort is therefore devoted to defining a coherent coastline and merging the different datasets into a continuous elevation model.

For the applications considered here, the resulting terrain model covers the entire Andalusian coastline, extending from the Gulf of Cádiz to the Alboran Sea. The combination of high-resolution datasets makes it possible to represent a wide range of coastal environments, from open beaches and estuaries to densely populated urban areas.

A particularly delicate aspect of this process is the definition of a consistent coastline. Since tsunami inundation depends critically on the interaction between the incoming wave and the land-sea interface, small inconsistencies in the representation of the shoreline may lead to significant errors in the estimated inundation extent. This effect is illustrated in Figure 5.

In practice, the coastline is not a sharply defined geometric object, but rather the result of combining bathymetric and

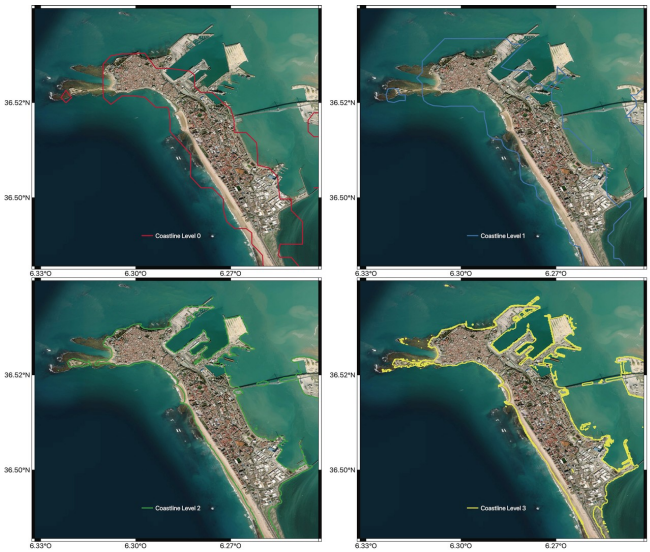


*Figure 5.* Evolution of the coastline definition in Cádiz as the resolution and consistency of the topobathymetric data improve. From coarse representations (top left) to a refined coastline (bottom right), the definition of the land–sea interface has a direct impact on the accuracy of inundation simulations. (Base imagery © Google Earth)

topographic data with different resolutions and measurement uncertainties. Ensuring a smooth and physically consistent transition between sea and land is therefore an essential step in the modelling workflow.

This example illustrates how the quality and consistency of the underlying geospatial data directly influence the reliability of tsunami inundation modelling, highlighting the importance of careful pre-processing in operational simulation workflows. From a numerical point of view, inconsistencies in the coastline definition may introduce spurious wetting and drying patterns, affecting both stability and accuracy of the solution.

### *3.2 Definition of worst-case tsunami scenarios*

Once the terrain model has been constructed, the next step in the workflow is the definition of tsunami generation scenarios. In the context of hazard assessment studies, these scenarios are designed to represent plausible earthquake sources capable of producing significant coastal impact.

Earthquake-generated tsunamis are typically modelled using subfault representations of the seismic source. In this approach, the fault plane is discretised into a set of rectangular patches, each of which is characterised by a small number of parameters describing the relative displacement of the two sides of the fault.

These parameters include the geometrical dimensions of the fault patches, their geographical location and depth, as well as their orientation in space through the strike and dip angles. The direction of slip is defined by the rake angle, while the slip magnitude determines the amount of displacement along the fault. Together, these parameters provide a compact description of the earthquake source that can be directly used in numerical simulations.

The displacement of the seafloor induced by the fault motion is then computed using elastic dislocation models, most commonly the formulation proposed by Okada [9]. This model provides an analytical solution for the deformation of an elastic half-space subject to slip on a finite rectangular fault. The resulting seafloor deformation is assumed to be instantaneously transferred to the ocean surface, providing the initial condition for the shallow water system.

Although this approach relies on simplifying assumptions, such as a flat seafloor and homogeneous elastic properties, it has proven to be a robust and widely used approximation in tsunami modelling. In practice, uncertainties in the fault parameters often dominate over the modelling errors introduced by these assumptions.

Within this hazard assessment workflow, these source models are used to define worst-case tsunami scenarios. For the Atlantic region, the worst-case scenario is defined through a composite fault model involving the Marquês de Pombal and Horseshoe segments [2]. The parameters defining this source are summarised in Table 1. In the Mediterranean region, multiple candidate seismic sources are considered. Their geographical distribution is illustrated in Figure 6.

*Table 1.* Parameters defining the Atlantic worst-case tsunami scenario, based on a composite fault model combining the Marquês de Pombal and Horseshoe segments.

| Fault | Lon (°) | Lat (°) | Depth (km) | L (km) | W (km) | Str. (°) | Dip (°) | Rake (°) | Slip (m) | $M_w$ |
|---|---|---|---|---|---|---|---|---|---|---|
| MdP | 10.25 | 36.64 | 5 | 120 | 80 | 20 | 35 | 90 | 12 | 8.8 |
| HS | 10.32 | 35.92 | 5 | 170 | 100 | 42 | 35 | 90 | 14 | |

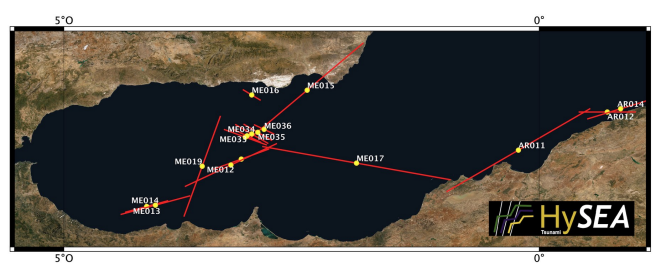


*Figure 6.* Seismic source scenarios considered in the Mediterranean region, derived from the QAFI database [5] and used to define a worst-case envelope of tsunami impact. (Basemap © Esri World Imagery)

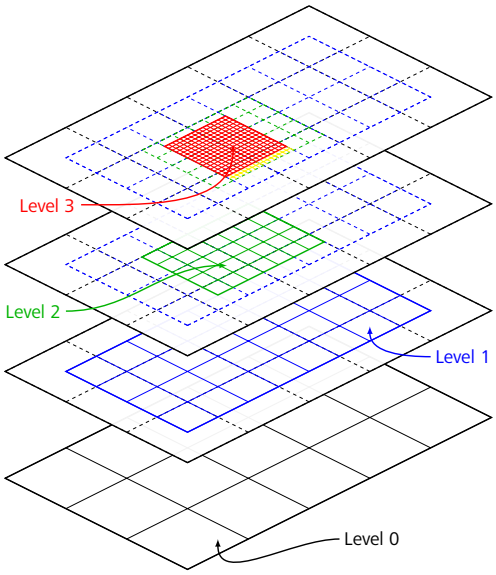


*Figure 7.* Schematic representation of nested grid strategies used in tsunami simulations. Coarse grids capture large-scale propagation, while finer grids resolve coastal inundation processes.

### *3.3 Nested grids for coastal inundation modelling*

Tsunami propagation involves a wide range of spatial scales, from ocean-basin dynamics to highly localised inundation processes near the coastline. From a numerical perspective, resolving this range of scales within a single computational grid would be prohibitively expensive, as it would require using a very fine resolution over the entire domain.

To overcome this limitation, tsunami simulations rely on nested grid strategies in which multiple computational meshes with different resolutions are coupled together. In this approach, coarse grids are used to simulate wave propagation across the open ocean, while progressively finer grids are introduced in coastal regions where higher accuracy is required.

Figure 7 illustrates this multi-resolution strategy. The nesting procedure allows the model to focus computational resources on regions of interest while maintaining an accurate representation of large-scale wave propagation.

In the Tsunami-HySEA model, a two-way nesting approach is employed. In contrast to one-way nesting, where information flows only from the coarse grid to the finer grids, two-way nesting allows feedback from the fine grids to the coarser levels. This improves the consistency of the numerical solution across different spatial scales, particularly in regions where coastal processes may influence the larger-scale flow.

Within the hazard assessment workflow, nested grids are constructed in a hierarchical manner, starting from a basin-scale propagation grid and refining progressively towards the coastline.

For the simulations considered here, four nested grid levels are employed. The outermost grid, with a resolution of approximately 320 m, captures the large-scale propagation of tsunami waves. This resolution is progressively refined to 80 m and 20 m in intermediate coastal grids, and further down to about 5 m in selected high-resolution target areas. At this finest scale, corresponding to 5 m per pixel, the computational domain comprises a total of 55,439,678 control volumes for the Atlantic region and 155,904,079 for the Mediterranean region.

The configuration used in these simulations is illustrated in Figure 8, which shows the nested grid structure applied to the Spanish coastline within the Copernicus framework.

Such high spatial resolution is essential for accurately representing tsunami inundation in complex coastal environments.

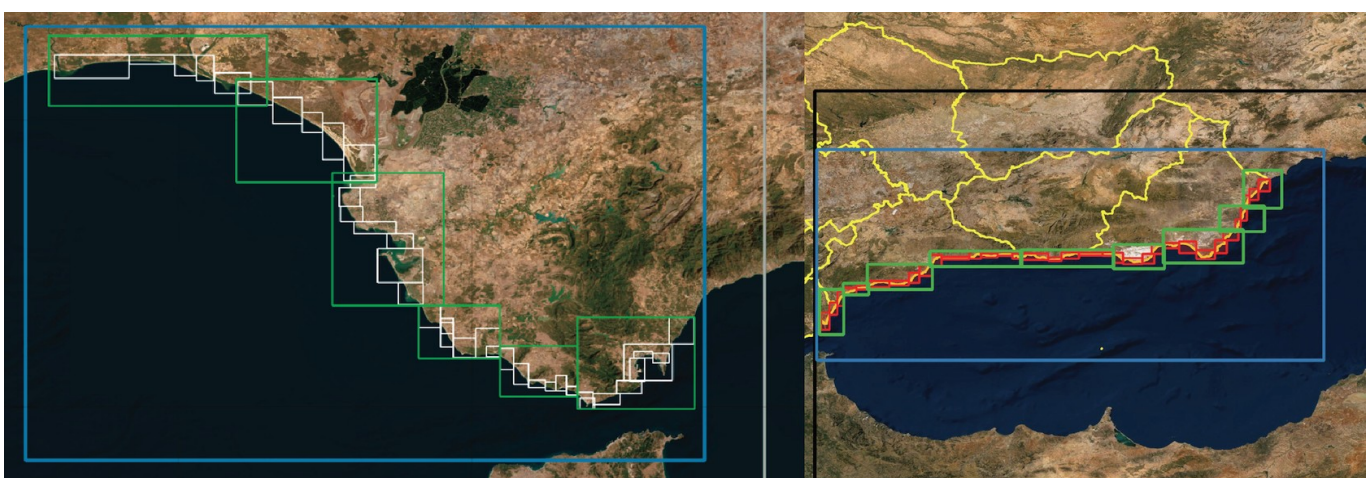

*Figure 8.* Spatial extent and distribution of the nested computational meshes defining the simulation domain, with resolutions ranging from 320 m (black) and 160 m (blue) to progressively finer grids of 20 m (green) and 5 m (white/red). Atlantic coast (left) and Mediterranean coast (right). (Basemap © Esri World Imagery)

At resolutions of a few metres, the numerical model begins to resolve the interaction of the flow with coastal features such as harbours, breakwaters and urban infrastructure, which play a key role in determining the extent and intensity of flooding.

From a computational perspective, nested grids provide a balance between accuracy and efficiency, allowing large-scale simulations to be performed while retaining the level of detail required for operational hazard assessment.

### *3.4 Large-scale simulations for risk assessment*

The combination of high-resolution terrain models, nested grids and multiple tsunami scenarios leads to numerical simulations of considerable size. Individual simulations may involve tens of millions of computational cells and require the solution of the governing equations over thousands of time steps.

To make these simulations feasible, the model have been implemented on modern high-performance computing architectures. In particular, GPU-based implementations allow the large number of finite-volume operations to be executed efficiently in parallel, significantly reducing computation times [4, 8].

These developments have been supported by several European HPC initiatives. The HySEA models are part of the ChEESE (Centre of Excellence for Exascale in Solid Earth) project, which focuses on developing advanced simulation tools for geophysical hazards. More recently, they have also been integrated into the eFlows4HPC project, aimed at combining high-performance simulation with data-driven workflows.

Within this framework, large-scale tsunami hazard assessments have been carried out along the Spanish coastline, reaching spatial resolutions of up to five metres in coastal areas. These simulations provide detailed estimates of inundation extent and water depth, which are essential for risk assessment and emergency planning.

The final outcome of this workflow is a set of high-resolution hazard products, including maps of maximum inundation depth, run-up and flood extent. These products are delivered within the Copernicus Emergency Management Service and are used by national and regional authorities to support coastal risk assessment, emergency planning and mitigation strategies.

### *3.5 Hazard indicators and simulation outputs*

The numerical simulations provide a detailed description of tsunami propagation and coastal impact through a set of physically meaningful indicators derived from the solution of the shallow water system. These quantities characterise both the large-scale dynamics of the wave and its local impact on coastal areas.

At the basin scale, the simulations allow the analysis of tsunami propagation through arrival times and maximum wave height. Arrival time maps provide a global view of the evolution of the tsunami front, highlighting the time available for potential warning and response.

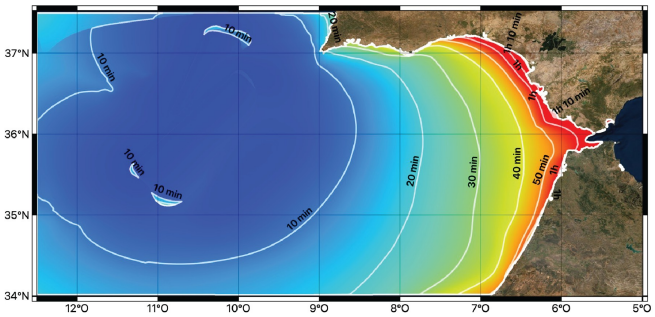


*Figure 9.* Arrival times of the tsunami wave for the selected Atlantic scenario. (Basemap © Esri World Imagery)

For instance, Figure 9 shows the spatial distribution of arrival times for the Atlantic worst-case scenario, revealing the progressive propagation of the tsunami wave towards the coastline.

A complementary perspective is obtained by considering one-dimensional profiles of arrival times along the coastline. An example associated with the Averroes fault in the Mediterranean region is shown in Figure 10, where the spatial variability of arrival times can be clearly observed.

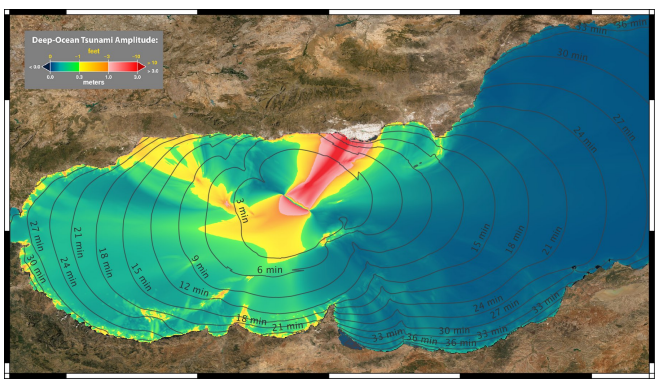


*Figure 10.* Arrival times along the coastline for the Averroes fault scenario in the Mediterranean region. (Basemap © Esri World Imagery)

A key difference between the Atlantic and Mediterranean scenarios lies in the characteristic time scales and wave amplitudes. In the Atlantic case, represented by a Lisbon-type worst-case event, the tsunami wave reaches the coast after approximately 50 minutes to one hour, with maximum wave heights of the order of several metres, reaching values close to 8 m in some locations.

In contrast, the Mediterranean scenarios are characterised by much shorter travel distances between the source and the coastline. As a result, the arrival time of the first wave can be as short as

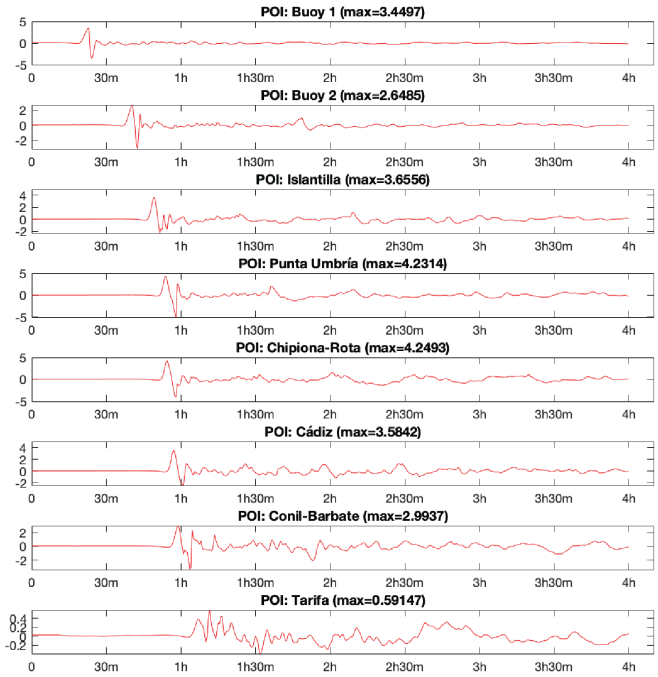


*Figure 11.* Time series of the free surface elevation at selected points of interest along the coastline.

approximately 15 minutes in the most exposed areas. However, these events typically generate lower wave amplitudes compared to the Atlantic case.

Moreover, due to the more complex seismic setting in the Mediterranean, hazard assessment is based on the analysis of multiple candidate sources. In this work, several scenarios are simulated and combined through an envelope approach, retaining the maximum impact obtained across the most critical events.

These differences have important implications for risk assessment and emergency planning. While the Atlantic scenario is dominated by higher wave amplitudes and longer warning times, the Mediterranean case is characterised by shorter response times, which place stronger constraints on early warning and evacuation strategies.

Complementary to this global description, time series of the free surface elevation are computed at virtual gauges distributed along the coastline. These signals provide detailed information on the temporal evolution of the tsunami, including wave amplitude, arrival sequence and duration of the event. In particular, they make it possible to identify multiple wave arrivals and resonance effects in specific locations, as illustrated in Figure 11.

As the tsunami approaches the coast, the analysis shifts from propagation to inundation processes. High-resolution simulations allow the computation of the maximum water depth over the flooded area, which determines both the spatial extent and the severity of the inundation. This variable is one of the most relevant indicators for hazard assessment, as it is directly related to potential damage to infrastructure and exposed assets. An example of maximum inundation depth in a coastal area is shown in Figure 12.

At finer spatial scales, the numerical model resolves the interaction between the flow and the built environment. This allows a detailed analysis of flooding patterns in urban areas, where local topography and infrastructure strongly influence the flow paths and water accumulation. Such simulations reveal complex features such as flow channelling along streets, local amplification in confined areas, and shadowing effects behind obstacles.

These effects are illustrated in Figures 1 and 13, which show high-resolution inundation patterns in representative coastal environments.

As the analysis moves from wave propagation to coastal inundation, high-resolution simulations provide detailed information on the extent and intensity of flooding. The combination of digital elevation models and simulated inundation patterns allows the identification of flood-prone areas with a high level of spatial accuracy.

These inundation maps form the basis for defining evacuation strategies. On the one hand, the horizontal extent of flooding supports the design of evacuation routes and the identification of safe meeting points outside the affected areas. On the other hand, the spatial distribution of water depth provides key information

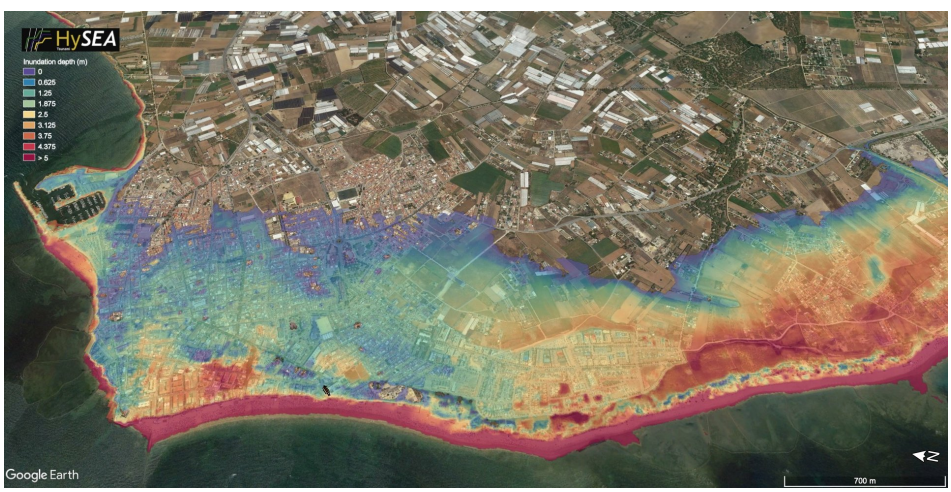


*Figure 12.* Maximum inundation depth in Chipiona (Cádiz). (Base imagery © Google Earth)

*Figure 13.* High-resolution inundation simulation in Málaga. (Base imagery © Google Earth, Landsat/Copernicus)

for vertical evacuation strategies, where the safety of upper floors in buildings can be assessed by combining inundation depth with building data and cadastral information.

This level of detail is only achievable through high-resolution simulations, where the interaction between the flow and the urban environment is explicitly resolved. In this context, inundation depth becomes a central variable, as it directly determines both the extent of flooding and the potential impact on exposed assets.

Building on this, these results have been translated into operational products for coastal risk management. In particular, the combination of high-resolution inundation maps with evacuation planning information has led to the development of interactive visualisation platforms.

An example of such a product is provided by the PEMAREA platform (Plan de Emergencia ante el Riesgo de Maremotos de Andalucía, Andalusian Tsunami Emergency Plan), which integrates tsunami hazard information with emergency planning layers at the regional scale.

Figure 14 shows an example of these products for the coastal town of Chipiona. The map combines the simulated inundation extent for worst-case scenarios with evacuation routes and designated safe meeting points, providing a comprehensive view of the potential impact and the corresponding response strategy.

In this representation, the inundation footprint derived from the numerical simulations defines the areas at risk, while the evacuation routes are designed to guide the population towards safe zones

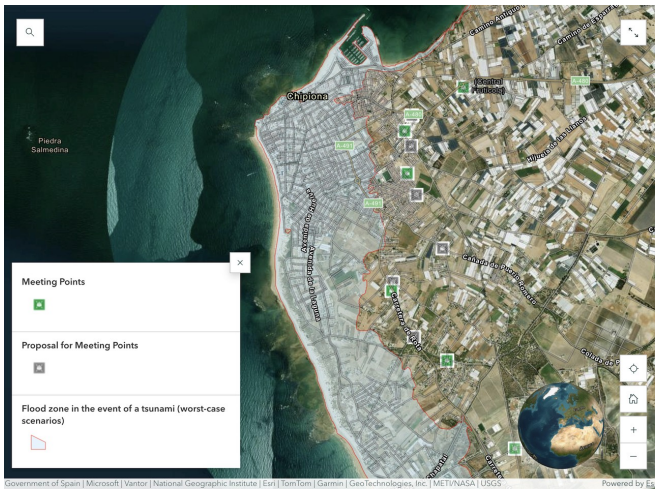


*Figure 14.* Example of an operational tsunami hazard product for Chipiona (Cádiz), derived from the PEMAREA platform, combining inundation extent, evacuation routes and designated meeting points. (Basemap © National Geographic Institute of Spain, Earthstar Geographics, Esri, TomTom, Garmin, FAO, NOAA, USGS)

outside the flooded region. The location of meeting points is determined by considering both accessibility and safety with respect to the maximum expected water levels.

This integration of simulation results with territorial information allows local authorities to design evacuation plans adapted to the specific characteristics of each coastal area. In particular, the combination of inundation depth with building data enables the assessment of vertical evacuation options, identifying structures where upper floors remain above the predicted flood levels.

From an operational perspective, these products provide a direct link between numerical modelling and emergency planning. Rather than being an abstract representation of tsunami dynamics, the simulation results are translated into actionable information that can be used to guide evacuation procedures and improve preparedness at the local scale.

## 4 Conclusions

In this work we have described the development of a modelling framework that connects mathematical theory, numerical simulation and operational applications in the context of tsunami hazard assessment.

Starting from depth-averaged descriptions of geophysical flows, we have shown how well-balanced finite-volume schemes, together with multi-resolution strategies and high-performance computing, make it possible to simulate tsunami propagation and inundation across a wide range of spatial scales. These developments allow both ocean-basin dynamics and highly localised coastal impact to be captured within a single computational framework.

Beyond the mathematical and numerical aspects, a key contribution of this work lies in the integration of these models into a complete workflow, including geospatial data processing, scenario definition and the generation of hazard indicators. This workflow has been implemented in operational hazard assessment contexts, where high-resolution simulations are used to create products supporting coastal risk assessment and emergency planning.

The results presented here illustrate how the solution of a system of conservation laws can be translated into actionable information, such as inundation maps, evacuation routes and hazard indicators. In this process, mathematical models provide not only a description of the physical phenomenon, but also a framework for decision-making.

A distinctive feature of tsunami modelling is that these decisions must be taken under significant uncertainty and, in some cases, within very limited time scales. The reliability, efficiency and robustness of the underlying numerical methods therefore become essential, as they directly influence the quality of the information available for risk assessment and emergency response.

More broadly, this work exemplifies how the interaction between mathematical modelling, numerical analysis, geospatial data and high-performance computing can lead to practical tools with direct societal impact. In the context of tsunami hazard assessment, this impact is measured not only in terms of scientific understanding, but also in the capacity to support preparedness and, ultimately, to contribute to the protection of human lives.

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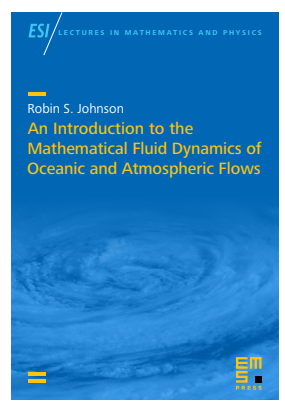


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# On Stefan Cohn-Vossen and his family

Bernd Kawohl and Michael Weigel

*Many mathematicians know and appreciate the book "Geometry and the imagination" by Hilbert and Cohn-Vossen* [15]*. It was first published in German in 1932 and has been translated into many languages. In contrast to David Hilbert, the second author, Stefan Cohn-Vossen, is less well known. In an effort to find out more about him, we realized that his life and that of his family had been affected by many dramatic and historic events.*

## 1 Stefan Cohn-Vossen

Bernhard Arnold Stefan Cohn-Vossen was born on May 28, 1902, in Breslau, Germany (now Wrocław, Poland) as the youngest of three brothers, and died on June 26, 1936, in Moscow. His mother Hedwig, née Vossen, was originally from Cologne; his father Emanuel Cohn was *Justizrat* in Breslau. Stefan Cohn-Vossen spent his childhood and youth in Breslau, where he attended the Johanneum, a highly respected secondary school. This school had several famous students, most notably Fritz Haber, a chemist and Nobel laureate (1918), Otto Stern, a physicist and Nobel laureate (1943), but also the mathematicians Wolfgang Fuchs and Otto Toeplitz. Emil Toeplitz, the father of Otto Toeplitz, was a mathematics teacher at the Johanneum. The school had a balanced distribution of Protestant, Catholic and Jewish teachers. In 1914, it had 280 Protestant, 70 Catholic and 180 Jewish students. To teach them mathematical reasoning the teachers used sets of constant width as an example. Consider the following two statements, (a) and (b) on a plane convex set $C$: (a) The set $C$ is a disc. (b) The set $C$ has constant width. Then (a) implies (b), but not vice versa, because there are many counterexamples, for instance the Reuleaux triangle. These sets of constant width are described in some detail in [21, Section 20].

As a teenager, Stefan Cohn-Vossen composed music and dedicated it to his mother, see [24]. When he graduated from the Johanneum, the Roaring Twenties had just begun.

Stefan Cohn-Vossen studied first in Breslau, then in Göttingen and again in Breslau. According to his mother's diary [6, p. 101f], he chose Göttingen because he was a member of the Zionist youth organization "Blauer Stern" (Blue Star) and its members had asked him to found a local chapter in Göttingen. In 1924, Stefan Cohn-Vossen received his doctoral degree in Breslau under Adolf Kneser [8]. The title of his dissertation was "Singular points of a family of curves with a given differential equation." This topic had been suggested by Guido Hoheisel. A single copy of the dissertation is preserved and can be found in the Staatsbibliothek zu Berlin. Grzegorz Karch searched for it in Wrocław and found the minutes of his oral examination for the PhD. The so-called Rigorosum included geology and Hebrew as subjects.

From 1924 to 1929 he had postdoctoral positions in Berlin and Göttingen. In [11] he described his scientific education and development.

In 1929 his habilitation took place in Göttingen. The original habilitation thesis "Non-rigid closed surfaces" [9] was also made available to us in facsimile by Richard Cohn-Vossen. On October 10, 1930, Stefan Cohn-Vossen became Privatdozent (lecturer) for "geometry and geometrical analysis" at the University of Cologne. In this tenured position his salary depended essentially on the number of students who enrolled in his classes.

On December 12, 1931, he married Elfriede Ranft, the daughter of a Protestant pastor from Saxony and a prospective physician. (Best men at the wedding in Holweide, Cologne were Hans Lewy

*Figure 1.* Stefan and Elfriede Cohn-Vossen.
(Photo courtesy of Richard Cohn-Vossen.)



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and Karl Dörge.) Since she was Protestant and he was Jewish, they did not have a religious wedding ceremony, much to the dismay of their four parents. Incidentally, the picture in Figure 1 was taken at their address Waldhausstr. 9 in Holweide, Cologne. Later they moved closer to the university, to Theresienstr. 20 in Lindenthal, Cologne [10]. In 1932 the book with Hilbert [15] appeared, and he gave his inaugural lecture on "convex surfaces" in the Aula Magna in Cologne. As we discovered only this year, Josef Naas was his doctoral student then. Naas was enrolled in Cologne from the summer of 1928 to 1933 and in 1935 he defended his doctoral thesis [20] in Cologne with Hans Ludwig Hamburger as official advisor, but in the CV accompanying his thesis he thanks both Cohn-Vossen and Hamburger for their advice and support. Stefan Cohn-Vossen and his wife continued to stay in touch with him.

In March 1933, Adolf Hitler and his party were democratically elected and in April a law was passed to the effect that Jews could no longer be public employees. According to [14, p. 109] on April 29, 1933, it was recommended to Cohn-Vossen that he should not exercise his right to teach (venia legendi), and on May 2, 1933, Christian Eckert (the then acting head of the University Curatorium) wrote a brief letter to him stating that, based on an April 29 cable from Berlin, he was temporarily suspended from teaching. In September 1933 the suspension became permanent. The curatorium was composed of scientists and a majority of seven representatives of the city [14, p. 30]. Until early April 1933, when he was ousted by the Nazis and went into hiding in a monastery, its head was the mayor of Cologne, Konrad Adenauer. Democratically elected governments can suddenly behave unlawfully, and we are currently seeing more examples of such behavior. No one stops them from doing so.

In any case, Stefan Cohn-Vossen had no income and no academic future in Germany. First he moved to Locarno in Switzerland where his parents had fled and tried to find employment elsewhere, for example, in Britain, France or the US. The archive of the British "Society for the Protection of Science and Learning," which tried to help displaced scientists in those days, has documents to this effect [3]. As references, he listed Blaschke from Hamburg, Carathéodory from Munich, Courant from New York, Erhard Schmidt from Berlin and Heinz Hopf from Zurich. From Locarno he moved to Klusstr. 7 in Zurich.

The photo in Figure 2 shows him with his wife and his mother in Switzerland, presumably at Lago Maggiore, as in a letter from September 1936 to the University of Cologne he left his parents' address in Locarno as his mailing address.

According to [26, p. 127], Charles Loewner recommended him for a position in the US in a letter to the head of Dartmouth College, Richard Courant recommended him for a chair at the newly established Istanbul University and Chaim Müntz from Leningrad and Fritz Houtermans from Kharkiv supported his application at Leningrad University. But also the topologist Heinz Hopf from Zurich

*Figure 2.* Hedwig, Stefan and Elfriede Cohn-Vossen. (Photo courtesy of Richard Cohn-Vossen.)

tried to help him find employment. He contacted James Stoker in Pittsburgh, who recommended Cohn-Vossen to his Carnegie Institute of Technology [16], and he wrote to Élie Cartan in Paris, Luitzen Egbertus Jan Brouwer in Amsterdam, Pavel Sergeyevich Alexandrov in Leningrad and Oswald Veblen in Princeton [17] on his behalf. Like Cohn-Vossen, Hopf had spent his youth in Breslau, and like Cohn-Vossen, Hopf was Jewish and married to a Protestant woman. In the end, Hopf's recommendation [18] to his coauthor, the Soviet topologist Pavel Sergeyevich Alexandrov [2], helped him to obtain an appointment at the Steklov Institute (located until 1935 in Leningrad, then moved to Moscow). Shortly before the appointment became official, in August 1934, he had also received a vague offer from the Academic Assistance Council in London (to be found in the Archive of the Society for the Protection of Science and Learning [3]) for a position at a so-called black college in Atlanta and had responded that he was interested in it, should his planned appointment in Leningrad not materialize.

Before they left for the Soviet Union, Stefan Cohn-Vossen and his wife had a son, David Hans Richard Cohn-Vossen, born on September 30, 1934. According to the family he was named after David Hilbert, Hans Lewy and Richard Courant. Under [24] the son quotes from a letter of his proud father to Josef Naas. This close friendship continued for many decades and was extended to Elfriede Cohn-Vossen and her second husband and later children. Incidentally, Stefan Cohn-Vossen had the nickname Confuz in those days. The emigration meant that the three had to become Soviet citizens, and thus lose German citizenship.

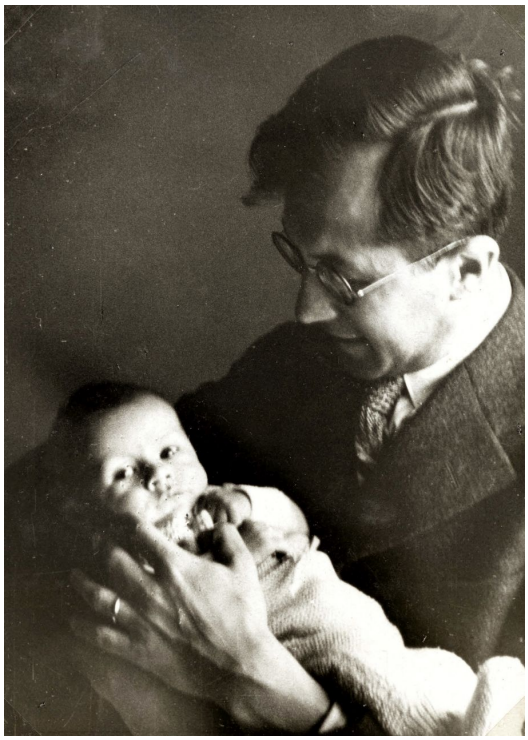

*Figure 3.* Stefan Cohn-Vossen and his son on the train to USSR. (Photo courtesy of Richard Cohn-Vossen.)

The photo in Figure 3 shows Cohn-Vossen with his son Richard on a train to Moscow in 1934.

In Leningrad the family lived at ul. Herzena 39 (now Bolshaya Morskaya ul.) close to the Hermitage.[1] Cohn-Vossen was welcomed into the circle of his colleagues and felt much at ease there. During this period he was extraordinarily academically productive; he wrote many papers and according to reports from his wife, he was often in a sort of mathematical flow or research mode, familiar to many mathematicians and their families. In this wonderful state all day-to-day worries tend to retreat into the background. According to a remark in [13, p. 86], see also [22, p. 251f], he also had a very gifted student, Vilkitsky, of whom no other record seems to exist.[1] His identity is unclear because a student by this or a similar name was enrolled neither in Leningrad nor in Cologne. Since the content of [20] and the remark in [13] are strongly related,[2] it is conceivable that the name Vilkitsky is a pseudonym for Josef Naas to avoid politically motivated problems by hiding the relationship between Josef Naas and Stefan Cohn-Vossen from public view.

Stefan Cohn-Vossen died on June 25, 1936, in Moscow, as a result of pneumonia [5, 7]. He had caught the infection in March 1936 during a train trip, and at that time no appropriate antibiotics were available. His wife reported on his bad health in a letter to the Hopf couple [5] and asked them not to tell his brother or parents because they might become too worried.

His death was also made public in the West, but apparently not noticed in Cologne. The paper "Existence of shortest paths" [12] that Cohn-Vossen had submitted for publication to the journal *Compositio Mathematica* on June 27, 1935, has a footnote: "Stefan Cohn-Vossen died at the age of 34 on June 25, 1936. The name of this colleague will live on in our journal, especially because of the extraordinary progress which his theorems concerning the shape of geodesics and total curvature of open surfaces […] contribute to geometry in the large."

In March 1946 the offer was made to him to return to the University of Cologne. We quote (and translate into English) from the letter of March 11, 1946, which can be found in [14, p. 405f]:

> "Dear Colleague,
> Since the Nazi regime has been removed, all directives have become invalid by which faculty members had been eliminated for racist or ideological reasons. I have been authorized by the Philosophical Faculty of the University of Cologne to request that you return to our university and take up the position that you once had. Indeed, it is a difficult task to return to Cologne, an almost completely destroyed city, and to start a new life. As intensive as our efforts are to re-establish our university, we will also do as much as is in our power to help you to resettle in Cologne. With best regards,
> Yours,
> Prof. Peter Rassow
> Dean of the Philosophical Faculty
> [Handwritten undated addendum:] According to information from Prof. Hamburger: Cohn-Vossen †"

It was mailed to his last known address in Switzerland and returned as undeliverable. Today the language of this letter seems almost cynical: not colleagues, but rather regulations drove Cohn-Vossen away and the return is not difficult because of the injustice he suffered, but rather because Cologne was in such a destroyed state!

In 1947, 11 years after his death, a long article by Aleksandr Danilovich Aleksandrov "On the works of S. E. Cohn-Vossen" was published in Russian, in a sense an academic epitaph [1]. The translation of this article into English was generously done by Andrei Iacob. The approval for the publication of the English version on the internet by the editors of the *Uspekhi Matematicheskich Nauk*, in particular Victor Buchstaber, was made possible in 2014 with the help of Ari Laptev, then director of the Mittag-Leffler Institute near Stockholm. Aleksandr Danilovich Aleksandrov was a differential geometer and lived from 1912 to 1999. Aleksandrov can certainly be counted among Cohn-Vossen's mathematical descendants, since after his doctoral thesis on weak convergence of

[1] Galina Sinkevich, personal communication.
[2] Alexander Lytchak, personal communication.

sequences he swung to the field of geometry. Among the students of Aleksandrov were Perelman (who refused the Fields medal), Bakelman, Burago and Zalgaller. Aleksandrov's article about Stefan Cohn-Vossen represents a very impressive commendation of his work. Moreover, in 1959 a collection of seven selected papers by Cohn-Vossen appeared in Russian translation [13]. In spite of his short lifespan, Cohn-Vossen had a seminal and lasting influence on his field.

## 2 His wife, Elfriede Cohn-Vossen

What happened to Stefan Cohn-Vossen's widow Elfriede Cohn-Vossen? She was now a Soviet citizen, had finished her medical studies and married Alfred Kurella, another exiled German and Soviet citizen, in 1938 in Moscow. They were neighbors in an apartment building at Ul. Bolshaya Kommunisticheskaya 24. The couple had two children together, a son Stefan Kurella in 1940 and a daughter Brigitte Kurella in 1945. When Germany attacked Moscow, Elfriede and her two little sons were evacuated from 1941 to 1943 to Chistopol (in Tatarstan), some 700 km east of Moscow. A vivid description of the transport can be found in [25, pp. 385–406]. There she worked in a hospital and raised the two children under extremely difficult conditions. Her husband had to stay essentially in Moscow. A published collection of letters that she exchanged with Alfred Kurella [19] bears witness to the incredible hardship that she had to endure and to her moral compass. According to Stefan Kurella, many of those letters were transferred in person by Boris Pasternak.

From 1946 to 1949 the family bought a house and lived in Pskhu, a picturesque mountain village in Abkhazia, about 60 km east of Sochi. Elfriede Cohn-Vossen worked in the hospital and took care of patients in surrounding villages, while Alfred Kurella wrote political poetry. Walter Ulbricht, head of state of the GDR, knew Alfred Kurella from their time at the Comintern in Moscow and wanted him back in Germany as a member of his political cadre. Therefore, Elfriede and Alfred returned first to Moscow (1949–54), and in 1954 they moved to Berlin, in 1955 to Leipzig and in 1958 back to Berlin. Brigitte Kurella recalls a visit of Josef Naas to Moscow in the early 1950s.[3] In 1957 Elfriede Cohn-Vossen died in a riding accident after her horse bolted.

Stefan Kurella had a polio-related handicap. He studied ethnology and worked at an institute for social medicine in Berlin, later as interpreter for Russian and French. After 1990 he worked on various projects, for a short time as chauffeur of Josef Naas,[4] and he founded an organization that raised money for a school in Pskhu. Brigitte Kurella studied medicine, worked as a neurophysiologist at the Humboldt University and later as head of a sleep lab. Josef Naas maintained close contact both with Richard Cohn-Vossen and his family and with Elfriede and her new Kurella branch of the family, also after Elfriede's death.

## 3 His son Richard and granddaughter Simone

In 1953 the son David Hans Richard of Stefan and Elfriede Cohn-Vossen began studying physics in Leningrad. There he first lived with Aleksandr Danilovich Aleksandrov and his wife in their apartment. In 1955, he joined his parents and siblings in Leipzig, where Alfred had become director of a newly established institute for literature. This included regaining (East) German citizenship. He was told by an official that he no longer could have three first names and that he had to choose the one he wanted to keep. After the death of his mother Richard no longer felt obliged to study physics. The family moved back to Berlin in 1958. He worked as an interpreter for DEFA (a film company) and later as a documentary filmmaker. We mention here just three of his films. In 1966/67 he made a remarkable documentary film on Paul Dessau, composer of music to Berthold Brecht's "Mother Courage and her children." This film won an award at the 16th International Filmweek in Mannheim (West Germany).[5] In 1970, he made a short film on the job of mathematicians and for mathematical expertise he received help from Josef Naas, then head of the Mathematical Institute of the Academy of Sciences in (East) Berlin. As mentioned before, Josef Naas had been a close friend of Richard's father Stefan and became a fatherly friend of Richard as soon as they met in Berlin. The commentary to this film about mathematicians was written by Wolfgang Thierse, who became a highly respected politician after the 1990 reunification of East and West Germany. To be precise, Thierse held the second-highest political position in Germany (Bundestagspräsident) as head of the German parliament from 1998 to 2005. In 1976 Richard Cohn-Vossen documented the everyday life of a porcelain worker's family in Ilmenau and refused to cut scenes in which socialism was criticized. Therefore, the film was not allowed into the theaters. It finally premiered in 2011, more than 20 years after the GDR had ceased to exist.

On November 13, 1976, Wolf Biermann, a political singer and songwriter, who had emigrated from West to East Germany in 1953, gave a concert in Cologne, West Germany. During the concert he criticized conditions in the GDR, whereupon his East German citizenship was revoked, so that he could not return. Richard Cohn-Vossen was one of the first to sign a petition on behalf of Wolf Biermann. He was urged to retract his signature and refused. As a consequence he lost his job and applied to move to West Germany. In 1979, he was finally allowed to do so, presumably because his pending application had started to raise unwanted publicity in the

[3] Brigitte Kurella, personal communication.

[4] Stefan Kurella, personal communication.

[5] https://www.iffmh.de/festival/history/1967

international film-making community. Some Spanish moviemakers had contacted his cousin Esteban Cohn-Vossen in Barcelona, who then tried to support his application. After settling in Hannover, Richard Cohn-Vossen worked for the NDR, a local radio and TV station in northern West Germany. Around 1980 he gave a radio interview to the WDR, a station located in Cologne, and mentioned that his father had been a mathematician. By pure chance Curt Meyer, a number theorist from Cologne, heard this interview on the radio and mentioned it to his colleague Peter Dombrowski, a differential geometer in Cologne, who had grown up in Breslau and who realized that Richard Cohn-Vossen could tell us about the fate of his father. Subsequently, he got in touch with Richard.

Richard Cohn-Vossen's daughter Simone became a theater actress. She recalls a visit to the weekend cottage of Josef Naas on an island in lake Teupitz, south of Berlin. Josef Naas had no children and had meant to leave his villa in Berlin-Pankow to Richard Cohn-Vossen, but Richard had moved away from Berlin and was no longer interested in it. Since Richard's half-sister Brigitte Kurella had taken care of Naas when he needed medical care in old age, he left it to Brigitte Kurella.

It is curious to note that in the summer of 1938 Naas had married Martha Jessen, the first wife of his official PhD advisor Hamburger, one year after their divorce in 1937. Martha and Josef Naas also suffered political persecution by the Nazis. As communists, they spent time in concentration camps. Martha Jessen died in 1983, Josef Naas in 1993.

## 4 His brothers and their families

Stefan (1902–1936) was much younger than his two brothers Berthold (called "Friedel") (1889–1933) and Walter Heinrich Gerhard (1892–1981). According to [6], they were both in relatively poor health and often ill. Therefore, during the First World War they were conscripted but never sent to the front, and thus they survived the war.

Friedel Cohn-Vossen was expected to become a lawyer and to take over his father's law firm. He was interested in poetry and the arts. According to [7, p. 57], he wrote poems, a major paper on Shakespeare and had learned French, Italian and Catalan in order to read classical poetry in those languages. His mother worried about him a great deal, but eventually he passed his examinations and started a successful law career. His last position was Verwaltungsgerichtsdirektor (head of the Administrative Court) in Wiesbaden. He married relatively late at the age of 42 on November 28, 1931. As a teenager, he was already aware of antisemitism and made two unsuccessful attempts to have his last name changed. As the Nazi movement gained momentum, in 1930 [7, p. 61] he recommended to his parents that they move their financial assets to Switzerland. On May 26, 1933, he committed suicide under the Nazi regime [7].

*Figure 4.* Friedel Cohn-Vossen. (Photo courtesy of Esteban Cohn-Vossen.)

Gerhard Cohn-Vossen, born on April 29, 1892, in Breslau, received a doctoral degree in law at Breslau and had a law firm in Dresden. He was a member of the Social Democratic Party and published political papers. His father had talked him out of a career in music. On May 24, 1928, he married Sophie Marckwald from Erdeborn. On September 2, 1930, they had a daughter Eva Barbara. In March 1933 his parents decided to emigrate and asked him and his family to come to Breslau for a farewell visit. Upon their return they were told that the police had already been looking for them because they were "Jewish communist pigs." The next day they fled to his grandmother in Teplice and from there in June 1933 to his parents in Locarno. Almost all of this and the following information is from [7]. Later Gerhard officially lost his PhD title, and of course his property.

*Figure 5.* Sophie and Gerhard Cohn-Vossen.
(Photo courtesy of Esteban Cohn-Vossen.)

In August 1933 Gerhard and Sophia emigrated further to Barcelona in Spain. Here Gerhard first tried to make a living by selling pharmaceuticals containing radium to doctors and pharmacists. In 1935, they were joined by Stefan's and Gerhard's parents, who moved into an apartment next door with all their belongings from Locarno. Meanwhile, Gerhard had met a Bavarian beer brewer who wanted to open a brewery in Spain and who was looking for an investor to help him. Thus, they made plans and rented a suitable villa for production with living accommodation upstairs in Moncada outside of Barcelona.

They managed to obtain a brewing permit, acquired the necessary equipment and started their microbrewery business from scratch at the beginning of 1936. This year brought much hardship. In the summer of 1936 they received news that Stefan Cohn-Vossen had died. Moreover, civil war had broken out in Spain and resulted in great chaos. The truck that was supposed to deliver their beer was confiscated, for example, so that they started selling and serving it on site, and their brewing partner left and went back to Germany. In October 1936 Gerhard's parents moved back to Locarno because they no longer felt safe. Also, Gerhard and Sophie decided to leave Spain, they put most of their belongings in storage and moved temporarily to a farm in southern France, where they lived under very rural conditions.

In the spring of 1937, under threat of confiscation of the brewery, Gerhard was forced to return and to start brewing again. His brewmaster was gone, so he experimented and managed to succeed. In the summer of 1937 Sophie and their daughter Eva also returned to Moncada. Since they had run out of supplies for the brewery during the next winter, they were allowed temporarily to close shop. They returned to Locarno. This involved obstacles such as walking 13 km from Moncada to the French consulate in Barcelona (and back) just to obtain visas for transit through France to Switzerland. Public transport had broken down, and they had no car. When the civil war in Spain ended and their temporary permission to stay in Switzerland, which had been repeatedly extended, finally expired in 1939, they tried to return to Spain, but now Germany was at war with France. After obtaining entry visas for Spain in January 1940, Gerhard took a plane from Rome and Sophie and Eva a ship from Genoa to Barcelona, with their modified German passports that had a red "J" (for Jewish) in them. The ship was stopped at sea by the French Navy and directed to Marseille where they spent a whole week on board and upon interrogation barely escaped imprisonment before the ship was allowed to continue to Barcelona, not without leaving much of its freight and some passengers in Marseille.

Their stored belongings had been put out on the street for grabs and by lucky coincidence [7, p. 139] they found some of their cabinets, one of which happened to contain Hedwig's diary [6]. Sophia saved and later transcribed this handwritten diary, and it is the only source of essential information about Stefan Cohn-Vossen's childhood in Breslau. They continued with brewing and running a beer garden in their old location in Moncada, and with much hard work they were able to make a living. When the German army had reached the Pyrenees and was threatening to enter Spain, they were so desperate that they planned to commit suicide and include their daughter, should this invasion start [6, p. 135]. Fortunately it did not, and after Hitler's Germany suffered losses in Africa, Italy and Russia, they gathered new hope and decided to have another child, Esteban Cohn-Vossen, who was born in January 1943. In 1956, they sold their brewing license and the business to a larger brewery (Damm) in Barcelona. The sales contract contained a clause that would grant their son lifelong employment in the new company, should he want it. In fact, Esteban became an engineer and worked in the new brewery until his retirement.

In the same year they received some financial compensation from the government of West Germany for the loss of their real estate which had been confiscated when they left Germany in 1933. Gerhard died in 1981 and Sophie in 1999, both in Barcelona.

Their daughter Eva trained as an opera singer, one of her classmates was Montserrat Caballè, and after some engagements at the Nuremberg opera she moved to France in 1959 to marry Zygmunt Ehrenfreund, a former acquaintance from Barcelona. Zygmunt Ehrenfreund was born May 26, 1923, in Jasło, a small town in the south of Poland that was occupied by the German army in September 1939. Together with his father Jacob, he fled to Lwów which belonged at that time to the Soviet-occupied part of Poland and today to Ukraine (Lviv). From there they were deported to Siberia, where they spent the entire Second World War. After their release in 1945 they were the only survivors of their entire family. They left Poland and spent a year in a camp for displaced persons near Salzburg. Jacob died there, and in 1946 Zygmunt had finally found refuge in France.[6] He worked as a textile merchant and after her marriage Eva became a German language teacher. In 1960, they had a daughter Gisèle, who became an interpreter, and in 1964 a son, Jacques, who holds a chair for Jewish history at Lausanne. Both children moved to Israel, as did Eva and Zygmunt after their retirement. Zygmunt died on June 19, 2009, and Eva on January 25, 2010, in Tel Aviv.

Meanwhile, the villa and former brewery in Moncada (today Montcada i Reixac) has been converted into a center for cultural events, named "Casa Larratea".[7]

## 5 His parents

Emanuel Cohn, born in 1860, and Hedwig Vohssen, born in 1863, were impressive personalities. Emanuel had 10 older brothers and

[6] Jacques Ehrenfreund, personal communication.

[7] https://www.montcada.cat/el-municipi/guia-del-municipi/equipaments/centre-cultural-casa-larratea

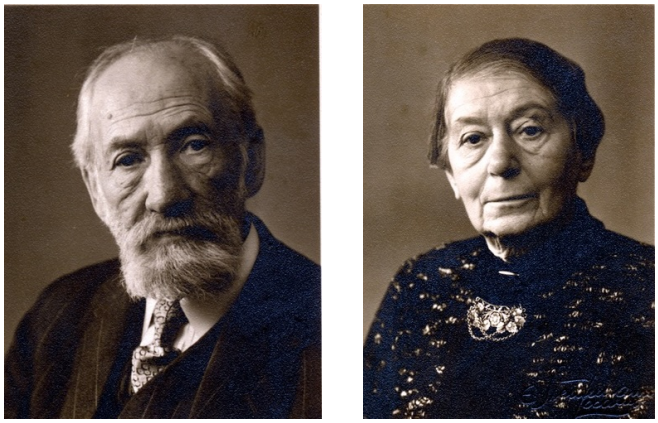

*Figure 6.* Emanuel and Hedwig Cohn-Vossen. (Photo courtesy of Esteban Cohn-Vossen.)

sisters. He grew up in the Silesian town of Oppeln (today Opole, Poland) and was the only one among the siblings to receive higher education. He studied law and his doctoral thesis (at the age of 23!) is available under [4]. He was a highly respected lawyer and notary. According to [7, pp. 54ff], the University of Breslau wanted to hire him as a professor, provided he would be baptized, which he refused. Since the surname Cohn was quite frequent, in 1919 Emanuel and Hedwig asked for and obtained permission to have it officially changed into Cohn-Vossen. This applied also to their children.

His wife Hedwig Helene Vohssen came from a rich merchant family; her father David Vohssen was co-owner of the company "Gideon & Vohssen" in Cologne while her mother Elise Perutz came from an upper class family in Teplitz (today Teplice, Czech Republic). Her maternal grandfather was successful as a banker and mine manager. Thus, Emanuel married into liberal circles. He and his father-in-law were Freemasons. Hedwig Vohssen was very much interested in both the arts and politics. She loved Italy and Italian architecture and made frequent trips, for instance to Venice [5]. Apparently she also corresponded with Jewish intellectuals. A letter of Franz Rosenzweig from March 7, 1918, addressed to her can be found in [23, p. 66f]. They discussed questions of Zionism, and also Hermann Badt participated in these discussions.

In Breslau the family had a rich social life, for instance, participating in the salon of Alfred and Toni Neisser, well-known philanthropists with a large art collection in their Villa Neisser. The Cohn-Vossens also lived in a villa in Kleinburg, a wealthy residential district of Breslau. Moreover, they owned another house with several rental apartments and they were well-off financially. Presumably part of their wealth came from Hedwig's considerable dowry.

She inspired her three sons with her intellectual versatility, in particular Stefan, who was not only interested in mathematics but also in music and politics. Much to her dismay, her husband Emanuel was not very interested in the arts and seemed to spend most of his time with his law office. He encouraged his two older sons Berthold and Gerhard to study law.

In March 1933 Emanuel and Hedwig Cohn-Vossen immigrated to Locarno, Switzerland. Except for a tentative attempt to settle in Barcelona in 1935/36, they stayed in Switzerland until their deaths in 1947 (Emanuel) and 1949 (Hedwig).

## 6 Epilogue

In 2014 a memorial colloquium for Stefan Cohn-Vossen took place in Cologne, during which a newly built seminar room was dedicated to him. The event was attended by his son Richard Cohn-Vossen and his nephew Esteban Cohn-Vossen, who generously contributed personal remembrances and all the photos in this article. Details on the event can be found via [24]. In his opening speech Vice-Rector Tassilo Küpper acknowledged the injustice that had been done to Stefan Cohn-Vossen by the University of Cologne and reported of a similar formal declaration from University of Wrocław (formerly the University of Breslau), which acknowledged the injustice done to Gerhard Cohn-Vossen through the revocation of his PhD title on March 15, 1940.[8]

*Acknowledgements.* We thank Richard, Esteban and Simone Cohn-Vossen as well as Peter Dombrowski for providing us with many private documents and photos. We thank also Michael Kiessling for bringing [3] and [26] to our attention, Joachim Rehberg for his help in obtaining [8], Michael Struwe for his help in retrieving [5] from the archives of the ETH Zurich, and Andreas Freitäger from the Cologne University Archives as well as Matt Foster from Oxford for providing us with documents from their archives.

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Michael Weigel is the information security officer (ISO) of a municipal housing company in Leipzig. His other interests include genealogy and social history. He is particularly interested in kinship and relationship networks of the early modern period. Through the Cohn-Vossens he is now also interested in the same aspects of the 20th century.

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# The myths of scientific edition

An awareness campaign

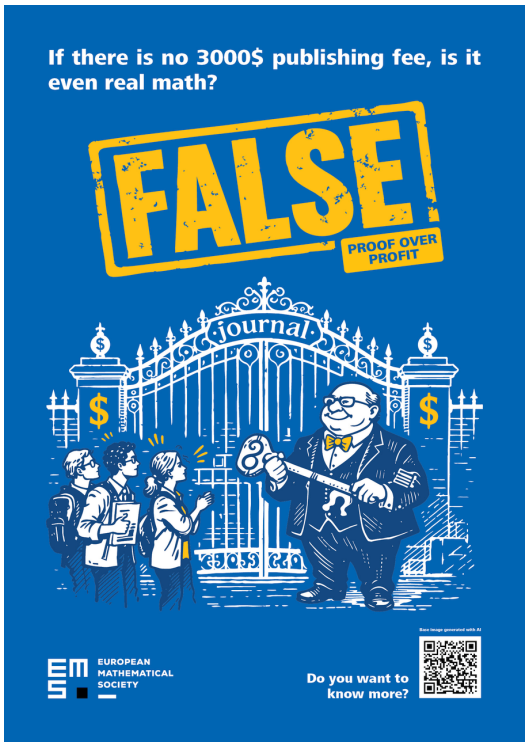
Christophe Ritzenthaler

You are walking down the street, and someone steals your wallet. Your first reflex? You run after the thief … only to hand over your watch as well. Then, once you get home, you call the city council to make sure this person is properly rewarded for their actions. Does this sound absurd? Yet, this is exactly what many of us do with our articles (our wallet), our time as reviewers or editors (our watch), and the funding of our institutions or governments when dealing with major commercial publishing houses like Springer, Elsevier, and others.

This 'triple taxation' along with the more recent drifts in the scientific publishing system (such as article processing charges (APCs), predatory journals, etc.) has already been widely commented on. It has been discussed in these very pages [7, 8], in numerous specialized journals and preprints [2, 4–6], and even in mainstream media [1, 3]. Some of you might feel a sense of *déjà-vu* reading these lines, and that is a sign that we are finally starting to address the issue at a scale commensurate with what is at stake (namely, our jobs and careers!).

Let us take a moment to pat ourselves on the back, as our community has not remained passive. Diamond open-access journals (free for both reader and author),[1] "Subscribe to Open" models like at EMS Press,[2] and journals supported by university presses that reinvest profits into the community are all on the rise. Initiatives are multiplying, much to the dismay of commercial publishers who are, naturally, fighting back. They do so by deliberately confusing Diamond and Gold open access, promoting ranking of journals based on bias factors, increasing APCs, scaling up *paper mills*, degrading reviewing standards, or imposing transformative agreements.

Naively, the solution seems to be within reach: after all, are we not already doing all the work? Not exactly: peer review, formatting, printing, or archiving, scientific publishing has a cost. It is much smaller in practice that the ones imposed by the big commercial editors (just look at their profits!), but it must be borne




by a benevolent actor (foundation, university, etc.). Once this is the case, implementing these changes takes time and energy, time that we would, of course, prefer to spend on our core business, which is research, rather than delving into the legal technicalities of publishing contracts.[3] There is also a scaling factor if we wanted to massively migrate all mathematical journals to absorb the annual production of our articles. The problem is in fact structural and much deeper: it is the entire system based on quantitative evaluation, on indices (impact factor and others), which is at the

[1] For a list of such journals, see the CIMPA Open Access node at https://www.cimpa.info/en/node/68 or the curated list of "mathematician-friendly" journals by K. Ramdani at https://karim-ramdani.perso.math.cnrs.fr/2025/11/14/quelques-revues-mathematicians-friendly/.

[2] https://ems.press/open-access/subscribe-to-open

[3] It may be an inspiring story to write down in another article the difficulties and obstacles created by Springer during the transition of the journal *Foundations of Computational Mathematics* (https://ems.press/journals/focm) to EMS Press.



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source of the multiple drifts we are witnessing today. It is sometimes difficult to realize the tsunami this represents when working in the West. For some countries where university funding is directly proportional to the number of articles, it is a disaster: a Pakistani colleague, an algebraic geometer by training, told me about his forced conversion to a more prolific field of research to avoid being fired!

In such a systemic context and faced with the unbridled imagination of commercial publishers, it is good to remain alert, to raise awareness among the younger generation about these issues, but without stigmatizing those in the most precarious situations. Five posters (two you can see here) were designed with this goal in mind and illustrate five 'false pretenses' or 'myths' spread by commercial lobbies:

- The Cost Myth
- The Ownership Myth
- The Metric Myth
- The 'Big Deal' Myth
- The Efficiency Myth

Each poster has a QR code allowing users to consult a short explanatory text and references to further understand the subject. I will let you discover them and will simply add a few words about the genesis of the project.

During the annual ERCOM[4] meeting at Institut Henri Poincaré in 2025, one of the discussion topics focused on issues related to scientific publishing. On this occasion, it was decided to create an awareness campaign, either in the form of posters, short videos[5] or webinars.[6] This is the first initiative to come to fruition thanks to the collective work of a small group of colleagues:

- Ilka Agricola,[7] chair of the IMU Committee on Publishing
- Markus Juvonen,[8] community engagement manager of the EMS
- Evelyne Miot,[9] chair of the EMS Committee on Publications and Electronic Dissemination
- Christophe Ritzenthaler,[10] chair of ERCOM
- Olaf Teschke,[11] managing editor of zbMATH

It would be unfair not to mention another major contributor: the ubiquitous AI, which helped us to draft the posters before they were finalized by the EMS Press graphic designer, Panna Tomori. A big thank you to her and to Heiko Schinke, who manages the ERCOM website where the documents are stored.

All this material is freely accessible on ERCOM webpage[12]: the posters can be downloaded and printed to be displayed wherever they might catch the attention of colleagues, especially in our research centers and conference venues.

Speaking of AI, our community is on the brink of massive upheaval.[13] Just as the excesses of commercial publishing force us to rethink how we disseminate knowledge, artificial intelligence challenges the very nature of how we produce it. While our immediate fear might be the proliferation of increasingly undetectable *AI slop*, the future could completely redefine what is expected of a researcher. Even more than today, we will need to emphasize values beyond sheer quantity or our simple role as *problem solvers*. We must focus on intelligibility and the added value of bringing new understanding to humanity. To use the words of Bill Thurston: *"The product of mathematics is clarity and understanding. Not theorems, by themselves."*

[4] https://ercom.org

[5] An example are the conference videos from a Simons Foundation workshop (https://www.simonsfoundation.org/event/mps-workshop-on-perspectives-on-electronic-information-communication-in-the-mathematical-sciences/).

[6] A notable example is the excellent series of webinars on publication and open access for doctoral students and young researchers organized by the French National Network of Mathematics Libraries (RNBM, https://www.rnbm.org).

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# Natural language search queries in zbMATH Open

Olaf Teschke

*In June 2026, zbMATH Open has released an experimental search option facilitating the translation of natural language queries into faceted search commands, taking full advantage of the traditional precise query language without requiring knowledge of its details.*

## 1 Introduction

Traditionally, zbMATH Open has offered two main access modes to its content: a one-line search function which allows both for simple searches and for a sophisticated syntax combining full logical expressions of now more than twenty fields, and a multi-line search providing a more traditional approach to combine these fields. The latter approach serves mainly as a reduced entrance barrier to the multitude of search dimensions. The various filter functions which can be applied to narrow results serve the same purpose. Overall, the guiding design philosophy is to facilitate both exhaustive and precise exploration instead of just convenient heuristics.

While expert users are usually aware of the core syntax and often employ complex pre-defined queries to obtain updates on their areas of interest, one cannot expect that all users have the full range of the ever-growing available functions in mind. E.g., information on arXiv versions [1], Open Access and licenses [4], or connections to Wikipedia [6] or research data like DLMF [2], OEIS [3], and the ATLAS of group representations have been added recently. At the same time, search habits change due to trends on other platforms, and may differ significantly among generations. Today, one may not always expect that the exact spelling of an author's name is needed, or that a precise Mathematics Subject Classification code is known for area search.

Hence, it is natural to employ recent advances in Artificial Intelligence (AI) – namely, the rapid progress of large language models (LLMs) – to overcome these barriers.

## 2 Large language models as an interpreting tool for zbMATH Open – benefits and limitations

LLMs now appear to be ubiquitous, and may be employed for very different purposes. For example, as described in an earlier article in this column [5], two LLMs have been very useful to overcome the long-lasting difficulties in translating scans of historical mathematical reviews into LaTeX and properly assigning them to metadata.

Still, the prevailing LLM application today appears to be a chatbot-like usage, which has also turned out to be helpful for math exploration – e.g., as a dialogue tool in pursuing proofs. However, such an installation at zbMATH Open appears not quite feasible; the main purpose of the service is not to create proofs, but to help identify what has been achieved, and what might be worth further investigation. Therefore, precision and comprehensiveness have been traditionally considered to be more important than convenient heuristics.

Instead, the new application of LLMs to zbMATH Open has a more modest goal: to allow for natural-language search queries without requiring full expert knowledge of the query syntax. The tool has been made available as a switchable experimental option at the One-Line Search for zbMATH Open documents in June 2026. When enabled, queries are translated into a Boolean combination of facet searches of the zbMATH query language that appear to fit the original question best, as in Figure 1, where the LLM correctly identifies the arXiv facet, the publication year range, and the content fields for a phrase from a natural language query.

There are some obvious advantages of this approach. Firstly, it reflects modern search customs, and overcomes the barrier of learning the query language. Even for expert users, it may no longer be necessary to keep track of all new developments and functions, as long as they are covered by appropriate prompt engineering.

Moreover, this usage allows users to avoid the mentioned problematic issues related to LLMs. No data from zbMATH Open needs to be ingested into the models, therefore avoiding license issues. Instead, the translation uses only appropriate prompt engineering based on general help and description texts for the zbMATH Open usage.

In addition, the technical implementation (see Section 3) also allows for a solution where no user input is employed, e.g., for training issues, and privacy is guaranteed.

On the other hand, users should be aware of the limitations of this feature. Naturally, only math-related queries which can be reasonably mapped to zbMATH Open fields will result in meaningful answers. Moreover, one cannot expect full reproducibility: Even

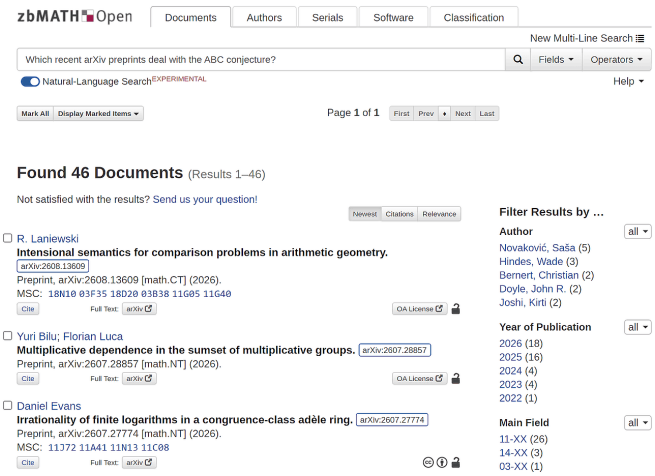


*Figure 1.* The query "Which recent arXiv preprints deal with the ABC conjecture?" is translated to "db:arxiv & py:2021-2026 & (ti:'ABC conjecture' | ab:'ABC conjecture' | ut:'ABC conjecture')."

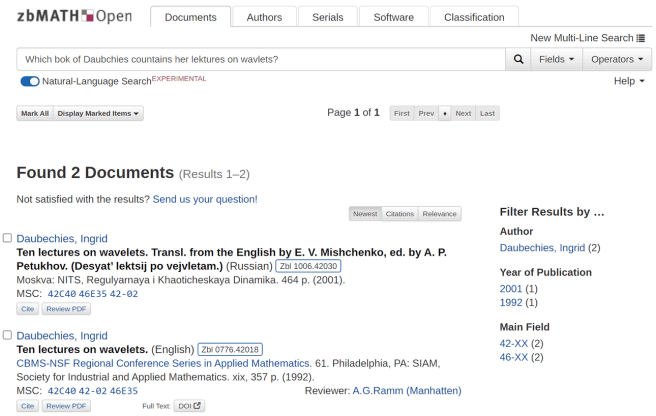


*Figure 2.* LLMs allow also for typo correction in queries like "Which bok of Daubchies countains her lektures on wavlets?"

the same language model will frequently produce different output for the same question, and the underlying LLM will be updated continuously to improve performance parameters (see Section 3).

Additionally, lacking billion-dollar resources of commercial AI companies, the service can only provide a limited amount of queries per specified units of time. When rate limits are reached, users may be forced to revert to traditional query types.

## 3 Technical implementation, models, and benchmarks

At a technical level, the natural language search is supported by the KISSKI LLM Service "Chat AI" provided by GWDG.[1] It offers a broad spectrum of recent open-weight models, both for web and API access. As mentioned, and perhaps most importantly, it guarantees no server-side storage of conversations. User input is not used for AI training or similar purposes, thereby avoiding any privacy conflicts.[2]

The list of currently available models can be found online[3]; versions and models are updated continuously. Experience from the test phase indicates that it makes sense to update the model underlying the zbMATH natural language search every few months, depending on the releases and the performance relative to the benchmarks.

For the initial benchmark suite, forty natural-language queries from typical questions occurring in the work of zbMATH section editors have been tested three times using several adapted prompts for the models, and evaluated with respect to robustness, output quality, performance, and token resources (with particular emphasis on the first two aspects).

At the time of writing, three models emerged at the top – Mistral Large Instruct 3 675B Instruct 2512, Qwen 3 32B, and OpenAI GPT OSS 120B. For all prompt versions, Mistral was by far the top model with respect to robustness and response time. The quality of the results varied depending on the prompts, but could be significantly improved for Mistral by prompt engineering to also beat the other models in this respect in the current setup. Hence, for the initial release, the Mistral Large Instruct 3 675B Instruct 2512 has been chosen (though at the time of publication, another model may be already in use).

## 4 Conclusions and future developments

The new query option intrinsically comes with some advantages which can be further exploited in the future. E.g., the LLM features allow for a reasonably good typo correction as in Figure 2.

Likewise, the models usually support (to a varying degree) multi-language queries, so English is no longer strictly necessary as input.

Obviously, it is not easy to foresee how effectively and successfully the natural language search will be adopted by zbMATH users. The further development depends very much upon the feedback, which can be provided through a specific contact form. In case of interest, we could also extend the current set of internal benchmark queries to a community-maintained open benchmark suite which helps keep pace with new LLM generations.

Currently, the natural language search has only been implemented for the document search, for the simple reason that it offers by far the most extensive search options, and the output is most helpful. Experiments with other search facets (like authors,

[1] https://kisski.gwdg.de/en/leistungen/2-02-llm-service/
[2] https://docs.hpc.gwdg.de/services/ai-services/chat-ai/faq/
[3] https://docs.hpc.gwdg.de/services/ai-services/chat-ai/models/

journals, or software) give no clear indication whether it might be useful to implement a similar feature through adapted prompts. Instead, it might be more helpful to create a large unified index of these facets combined with document search. Obviously, this would also require much more fine-tuning of the LLM layer, and it makes sense to gain initial experience with the release of the search for documents only. Such an LLM-supported unified search would obviously also be convenient for mobile versions of the database.

*Acknowledgements.* The author would like to thank Christian Bär, Andreas Kühnemund, and Fabian Müller for many ideas, discussions, implementations, and tests which made the new feature possible and formed the basis of this note.

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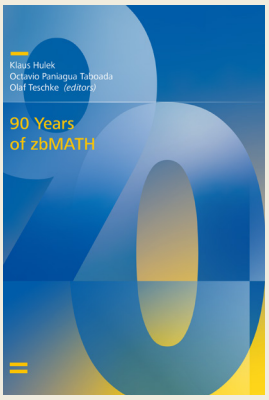
## EMS Press book




**90 Years of zbMATH**

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Octavio Paniagua Taboada
(FIZ Karlsruhe)
Olaf Teschke
(FIZ Karlsruhe)

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zbMATH Open, the world's most comprehensive and longest-running abstracting and reviewing service in pure and applied mathematics was founded by Otto Neugebauer in 1931. It celebrated its 90th anniversary by becoming an open access database. In December 2019, the Joint Science Conference (Gemeinsame Wissenschaftskonferenz) agreed that the Federal and State Governments of Germany would support FIZ Karlsruhe in transforming zbMATH into an open platform. In future, zbMATH Open will link mathematical services and platforms so as to provide considerably more content for further research and collaborative work in mathematics and related fields.

This book presents how zbMATH Open has reacted to a rapidly changing digital era. Topics covered include: the linkage of zbMATH Open with different community platforms and digital maths libraries, the use of zbMATH Open as a bibliographical tool, API solutions, current advancements in author profiles, the indexing of mathematical software packages (swMATH), and issues concerning mathematical formula search in zbMATH Open. We also reflect on the gender publication gap in mathematics, and focus on one of the central pillars of zbMATH Open: the community of reviewers.

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# Introducing IPYA: the Inverse Problems Young Academy

EMYA column regularly presented by Jesse Railo

Giovanni Covi, Nataliia Kinash and Rommel Rabongue Real

IPYA, the Inverse Problems Young Academy, is the official international association of young researchers working in inverse problems. It has been founded on 1 August 2025 by IPIA, the Inverse Problems International Association, on the occasion of the conference AIP 2025 on applied inverse problems, held in Rio de Janeiro, Brazil.

IPYA's mission consists in engaging early-career researchers in the field of inverse problems and amplifying their voices within the scientific community. It aims to promoting scientific activities of interest to early-stage researchers, by organising opportunities to develop research and academic skills, and facilitating connections among young researchers.

At the moment of writing, IPYA consists of 21 members, representing the young inverse problems community in 12 countries and 4 continents (North America, Europe, Africa, and Asia). Membership lasts 3 years, and one new cohort of about 20 members is planned to join the Academy every year.

The philosophy of IPYA is one of democracy: all members get a vote in all major decisions. Moreover, all concerns, projects and opinions of members find an open space for discussion. To achieve its goals, IPYA has given itself an official statute modelled on that of EMYA – the European Mathematical Society Young Academy. In order to realise the plans decided by its members, IPYA has given itself a committee, whose members are elected by the general assembly of the Academy. The work of the IPYA committee consists in taking concrete action towards the achievement of IPYA's goals. The current Chair and Secretary of IPYA are Giovanni Covi (University of Jyväskylä, Finland) and Pu-Zhao Kow (National Chengchi University, Taiwan).

## 1 Activities

The flagship activity of IPYA is its online seminar series, *Frontiers in inverse problems: theory, algorithms, and applications*, run biweekly on Thursdays at 13:00 GMT. The series launched in November 2025 and is curated by a scientific committee comprising Ping Liu, Pu-Zhao Kow, Suman Kumar Sahoo, and Yaohua Zang. Each session features a single 30–60 minute talk, with a primary focus on early-career speakers, although senior researchers are warmly invited to contribute as well. Talks held to date span the full breadth advertised in the series' title, including nonlocality and the fractional Calderón problem (G. Covi), inverse problems for the prescribed mean curvature equation (J. Nurminen), the geometrisation of elasticity and ray tomography (A. Kykkänen), heuristic parameter-choice rules for Tikhonov and Landweber regularisation (R. R. Real), physics-informed generative neural operators for PDE-based inversion (Y. Zang), convergence of the Levenberg–Marquardt method under Hölder stability (A. Ishida), and Bayesian contraction rates for inverse source problems (P.-Z. Kow). Talk announcements are communicated through the seminar's public repository.[1] Beyond the seminar, IPYA holds regular general meetings to coordinate its scientific agenda, and is actively exploring further initiatives such as special sessions at conferences and special issues in journals, alongside outreach to the early-career sections of sister societies including the EMS and AMS. We stress that all IPYA scientific activities are open to the entire community of young researchers in inverse problems, and are by no means restricted to IPYA members.

## 2 The path to the founding of IPYA

On 22 February 2025, the Executive Committee of the Inverse Problems International Association (IPIA) released the first call for applications for the Inverse Problems Young Academy (IPYA). The goal of installing IPYA was to attract early stage researchers to the field of Inverse problems and give them a voice in the scientific community. During June of the same year, the 21 founding members from different countries were informed, and on 8 July 2025, they had their first-ever online meeting presided over by the IPIA president Barbara Kaltenbacher. IPYA held its first official General meeting on 28 July 2025 in hybrid format, some of the members having met at the international conference AIP 2025 held in Rio de Janeiro, Brazil. As a result, it was decided that the official foundation of IPYA would be on 1 August 2025.

[1] https://github.com/IPYA-site/IPYA_seminar



EMS MAGAZINE 141 (2026) — DOI 10.4171/MAG/324

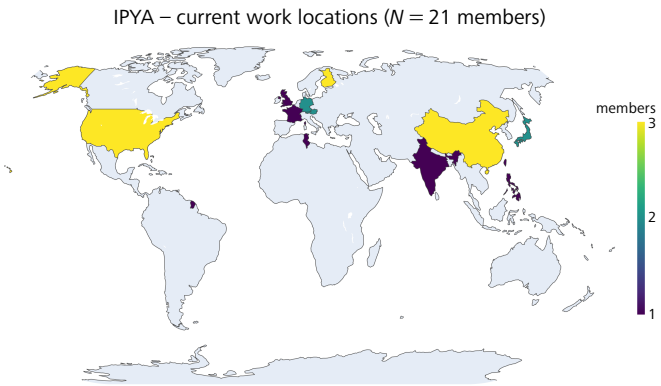


*Figure 1.* Current work locations of IPYA members, colour coded by number of members per country.

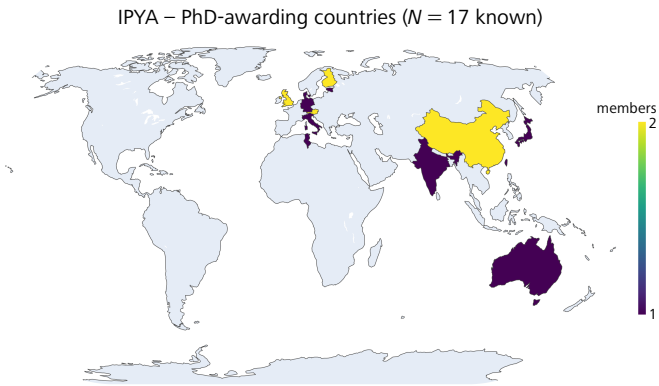


*Figure 2.* PhD-awarding countries of the IPYA membership.

## 3 Members

The IPYA currently brings together 21 early-career researchers working on inverse problems, based at 20 institutions across 12 countries and 4 continents. The membership ranges from PhD students to a tenure-track associate professor, with research interests that span the field – from purely theoretical work on Calderón-type problems and integral geometry to deep learning, photoacoustic tomography, and bio-heat modelling.

*Career stage.* Reflecting the Academy's commitment to *young* researchers, the largest group is postdoctoral fellows (9 members), followed by assistant professors (5), PhD students (2), lecturers (2), and one associate professor. The average career age is 2.3 years post-PhD, confirming that the Academy is firmly anchored in the early stages of an independent research career.

*Geographical reach.* Members are currently based in Europe (9), Asia (8), North America (3), and Africa (1), with the largest concentrations in Finland, China, and the United States (3 members each), and further representation in Germany, Japan, Austria, and single members in France, the United Kingdom, India, the Philippines, Tunisia, and Taiwan (see Figure 1). The members hold doctorates from 13 different countries, including smaller mathematical centres such as Estonia, Denmark, Italy, and Tunisia alongside the major hubs in the United Kingdom, Finland, Austria, and China (see Figure 2).

*International mobility.* Comparing each member's PhD country with their current institution, nine of seventeen members with a known PhD country (53%) currently work in a different country than the one in which they were trained, illustrating the strongly international character of the inverse problems community.

*Research themes.* The unifying thread is naturally inverse problems, which appear in every member's research statement. However, the members' expertise and interests reach much further than this – and indeed the members were selected in order to grant representation to all the main subfields of inverse problems. See Figure 3 for a taste of the full extent of IPYA members' research topics.

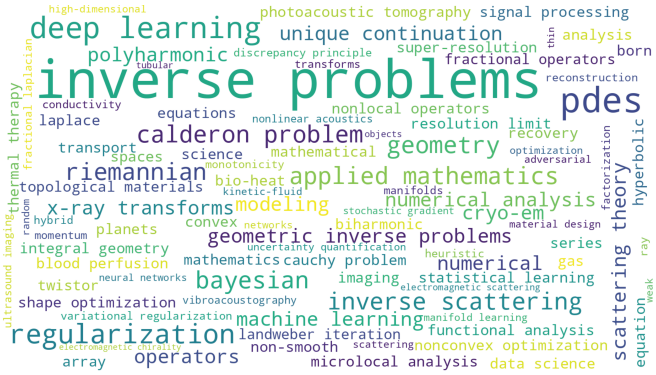


*Figure 3.* Word cloud of the IPYA membership's research focus and particular interests.

## 4 Get involved

Participation in IPYA seminars, meetings, and all other initiatives is open to all young researchers: IPYA membership is not required, and we warmly encourage interested colleagues to follow the seminar series and to engage with us through the IPYA website.[2] On the webpage it is also possible to find the list of all IPYA members, most of whom provide a link to a personal webpage and an email address. New members join annually through a joint call with IPIA.

[2] https://ipia.site/wp/about-ipya/

In order to apply:

- *Check your eligibility:* Early-stage researchers, from their third PhD year up to five years post-PhD as of the application deadline, are welcome to apply to become a member of the Academy by answering to the yearly open call. You do not need to be a member of IPIA in order to apply – rather, you will automatically become one when you will be selected as an IPYA member!
- *Prepare your application materials:* You will need a motivation letter, a CV, and the names of two referees. The referees will usually be IPIA members themselves.
- *Pay attention to the deadline:* The most recent call closed on 15 April 2026. The next call is expected to open in 2027, and information about this will become available on the IPIA website.[3] It is of course beneficial for all prospective members to join our activities even before the call!
- *Selection process:* Approximately 20 new members are chosen per year by a selection committee appointed by the IPIA Executive Committee, on the basis of scientific excellence (relative to academic age) and commitment to advancing the aims of IPYA, with attention to gender, regional, and mathematical diversity. Two members of IPYA also take part in the selection committee, which ensures that the decision process respects the will of the Academy. The second IPYA cohort is expected to be announced during summer 2026.

If you believe that IPYA would be a good match for you, please consider contacting us: we would love to hear from you!

Giovanni Covi is a senior lecturer at the University of Jyväskylä, Finland, and the chair of IPYA. He earned his PhD in mathematical analysis and inverse problems from the University of Jyväskylä, Finland, in 2020. His research focuses primarily on inverse problems for PDEs, with particular interest in nonlocal operators and unique continuation.

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[3] https://ipia.site

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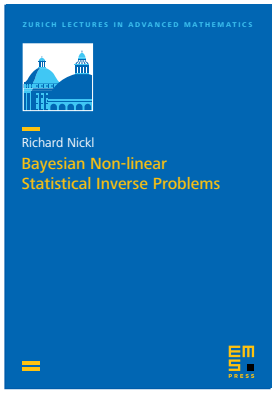


**Bayesian Non-linear Statistical Inverse Problems**

Richard Nickl
(University of Cambridge)

Zurich Lectures in Advanced Mathematics

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The present book presents a rigorous mathematical analysis of the statistical performance, and algorithmic complexity, of Bayesian methods based on Gaussian process priors in a natural setting of non-linear random design regression.

Due to the non-linearity present in many of these inverse problems, natural least squares functionals are non-convex and the Bayesian paradigm presents an attractive alternative to optimisation-based approaches. This book develops a general theory of Bayesian inference for non-linear forward maps and rigorously considers two PDE model examples arising with Darcy's problem and a Schrödinger equation. The focus is initially on statistical consistency of Gaussian process methods, and then moves on to study local fluctuations and approximations of posterior distributions by Gaussian or log-concave measures whose curvature is described by PDE mapping properties of underlying 'information operators'. Applications to the algorithmic runtime of gradient-based MCMC methods are discussed as well as computation time lower bounds for worst case performance of some algorithms.

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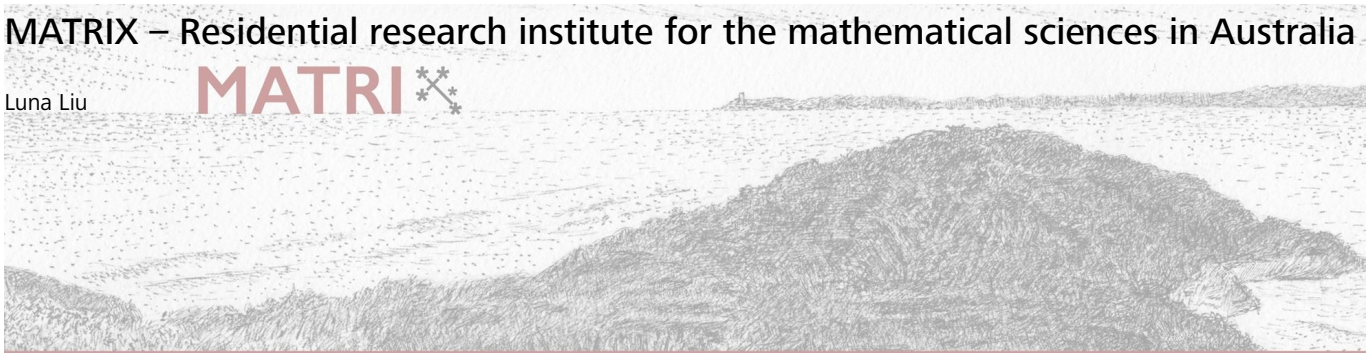
# MATRIX – Residential research institute for the mathematical sciences in Australia

Luna Liu




## About the institute

MATRIX[1] is Australia's residential research institute for the mathematical sciences, situated on Dja Dja Wurrung traditional land in Creswick, Victoria, Australia. MATRIX offers a uniquely Australian and immersive environment to host research programs for mathematical sciences researchers in Australia and the Asia-Pacific region, their global peers, as well as those in business, industry, and government.

*Figure 1.* Kangaroos feature on the institute's campus.

MATRIX is supported through a consortium of leading Australian universities. MATRIX has also received support from the Simons Foundation[2] and the Australian Research Council (ARC).[3]

[1] https://www.matrix-inst.org.au/about-us/
[2] https://www.simonsfoundation.org
[3] https://www.arc.gov.au

## History of the institute

MATRIX was initiated in 2015 by the Australian Research Council Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) and launched in 2016 as a partnership between the University of Melbourne and Monash University. The Australian National University joined as a full partner in 2020, followed by the University of Queensland in 2024 after a period as an associate member from 2021 to 2023. MATRIX has continued to expand its partnership, with the University of New South Wales joining as an associate member in 2025, followed by Adelaide University and the University of Sydney in 2026.

## Governance and leadership

MATRIX's governance structure includes a Stakeholder Group, Advisory Board, Scientific Committee, and Executive Team. The Executive Team sets strategy and oversees the operation of MATRIX and consists of Jan de Gier (director), David Wood, Joe Grotowski (deputy directors) and Tom Keegan (senior executive officer). The Advisory Board offers strategic advice and recommendations to the Executive Team and Scientific Committee on MATRIX's direction and activities. An independent Scientific Committee selects MATRIX research programs.

Since its launch in 2016, MATRIX has fostered international collaboration through 129 residential research programs, attracting over 3,200 scientists from 49 countries.

## Scientific activities

MATRIX research programs[4] encompass a broad spectrum of mathematical sciences, including pure and applied mathematics, statistics, data science, mathematical physics, and computational mathematics. These programs are organised by researchers from

[4] https://www.matrix-inst.org.au/events-01/programs/

*Figure 2.* Group photos from PhD student-led symposia.

universities across Australia and globally, and delve into diverse areas such as mathematical biology, quantum systems, AI and machine learning, complex systems, discrete mathematics, geometry and topology, finance, and high-dimensional computing.

Recent examples of research programs at MATRIX include the 2025 program *Numerical Analysis of Interface and Multiphysics Problems* on novel numerical methods of relevance to geophysical flows and biomechanics, where moving domains and interface dynamics play major roles. The 2025 program *Bayesian Learning of Very High-Dimensional Physical Process Models* addressed AI/ML advances in complex processes such as computer-generated human conversations or photorealistic images. The 2025 MATRIX-MFO Tandem Workshop on *Machine Learning and AI for Mathematics* focused on how AI methods can help mathematicians advance mathematics, and how problems of mathematics can serve as benchmarks, and the 2026 program *Symmetric Functions and Stochastic Processes* will strengthen ties between integrable probability, symmetric function theory, and stochastic processes.

**Past highlights**

**The geometry of moduli spaces in string theory (2024)** with Philip Candelas and Xenia de la Ossa from Oxford.

**Algebraic geometry (2024)** with Caucher Birkar from Cambridge.

**Computational mathematics for high-dimensional data in statistical learning (2023)** with Art Owen from Stanford.

**Structural graph theory downunder (2019)** with Maria Chudnovsky and Paul Seymour from Princeton.

MATRIX also hosts PhD student-led symposia[5] (Figure 2) in partnership with the Australian Mathematical Sciences Institute (AMSI) which have been transformative, offering young mathematicians invaluable opportunities for growth and collaboration.

The MATRIX Book Series[6] (Figure 3), published by Springer, documents research outcomes generated at MATRIX.

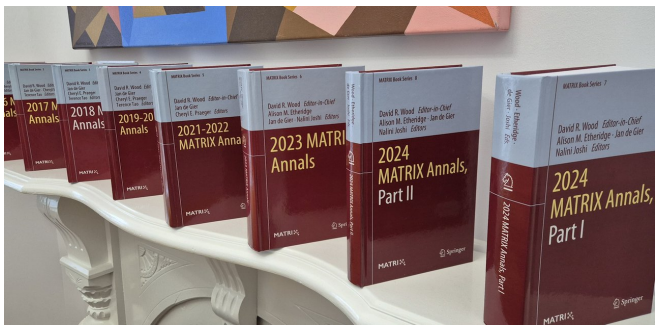



*Figure 3.* MATRIX Annals.

## Research facility and supportive research culture

MATRIX provides a central location where mathematical scientists collaborate through residential research programs for 1–4 weeks. Located in the regional town of Creswick, Victoria, 90 minutes west of Melbourne and surrounded by natural forest (Figure 4), MATRIX offers dedicated research spaces, lecture facilities, on-site

*Figure 4.* Trees on the campus.

[5] https://www.matrix-inst.org.au/events-01/phd-student-research-symposia/

[6] https://www.matrix-inst.org.au/book-series/

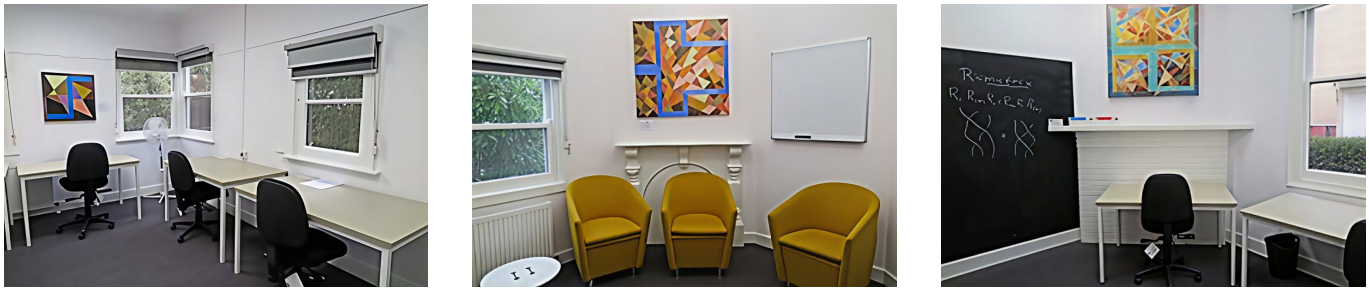


*Figure 5.* Research environment at MATRIX.

accommodation and meals, and communal areas that encourage informal discussion and knowledge exchange beyond traditional academic settings.

In addition to its residential research facilities (Figure 5), MATRIX is committed to fostering an inclusive and supportive research environment through initiatives such as the MATRIX Family Fund, which assists researchers with carer responsibilities by providing practical support including travel assistance, accommodation support, and access to childcare services when needed. This targeted support addresses a critical barrier faced by researchers with carer responsibilities.

## A decade of growth

In 2025, MATRIX celebrated its 10th anniversary,[7] marking a decade of growth from modest beginnings into an internationally recognised hub for the mathematical sciences in Australia. Since its inception, MATRIX has built a global network for knowledge exchange and collaboration, partnering with the Simons Laufer Mathematical Sciences Institute (SLMath)[8] in Berkeley, Mathematisches Forschungsinstitut Oberwolfach (MFO)[9] in Germany, the Institute for Basic Science (IBS)[10] in South Korea, the Research Institute for Mathematical Sciences (RIMS)[11] in Japan and Banff International Research Station (BIRS)[12] in Canada.

This milestone was celebrated together with partner institutions, program organisers, participants, supporters, and the broader mathematical sciences community, reflecting ten years of shared vision, collaboration, and intellectual leadership.

*"The vision for MATRIX was to create a place where ideas could flourish through sustained, in-person collaboration,"* said Jan de Gier, founding director of MATRIX. *"Ten years on, that vision has been realised beyond our expectations. MATRIX is now internationally recognised as a centre for mathematical excellence."*

Over the past decade, MATRIX programs have contributed to new scientific advances and new research partnerships, while strengthening Australia's mathematical sciences ecosystem. As it enters its second decade, MATRIX remains committed to fostering world-class mathematical research in Australia.

Luna Liu is the engagement and development professional at MATRIX, Australia's residential research institute for the mathematical sciences, where she leads communications, philanthropy, and stakeholder engagement activities. She has lived and studied in Asia and Europe and brings over a decade of experience across NGOs and the Australian higher education sector. She values the importance of fundamental science and is passionate about supporting and promoting mathematical research and talent.

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[7] https://www.youtube.com/watch?v=PDWcANR-nLQ
[8] https://www.slmath.org
[9] https://www.mfo.de
[10] https://www.ibs.re.kr/eng/sub02_02.do
[11] https://www.kurims.kyoto-u.ac.jp/en/
[12] https://www.birs.ca

# A spring gathering in Belgrade

Markus Juvonen

*Report from the EMS Executive Committee and ERCOM meetings in Belgrade, 19–21 March 2026.*

Belgrade offered a memorable setting for the March 2026 meetings of the EMS Executive Committee[1] (EC) and the EMS Union of European Research Centres on Mathematics[2] (ERCOM). The evening before the meetings began, the organisers welcomed participants with a visit to the National Museum of Serbia, followed by the opening ceremony of the 80th anniversary of the Mathematical Institute of the Serbian Academy of Sciences and Arts. It was a warm and thoughtful welcome before the long meeting days ahead, and offered an early opportunity to encounter not only the host institution, but also something of the history of the place and of Serbian scientific and cultural life. A separate article by Marija Šegan-Radonjić and Đorđe Baralić in this issue offers a closer look at the institute's 80-year history.

The EC meeting began on 19 March with participants welcomed on behalf of the host institution by Đorđe Baralić of the Mathematical Institute SANU. Attending the EC meeting in person for the first time after taking over as community engagement manager (CEM) gave it a particular feel: many of the colleagues present had so far been known to me mainly through online exchanges, and meeting them face to face made the work of the Society feel more immediate and more connected.

The EC agenda was, as usual, broad. Rather than going through every technical and procedural detail, I will focus here on a few themes from the Belgrade discussions that are of more direct interest to EMS members and the wider mathematical community.

One important strand of the Belgrade discussions concerned the Society's financial planning and long-term sustainability. The EC considered the budget framework for 2027 and 2028, including proposed small increases to membership fees, higher salary costs linked to the transition of the CEM role to full-time employment, and the need to budget for website and database development and maintenance.

EC meeting participants in front of Europe House Belgrade, venue for the first day of the meeting.

Since the EC autumn meeting, the EMS has also welcomed two new institutional members: the Institute of Mathematics, Physics and Mechanics in Ljubljana and the Max Planck Institute for Mathematics in Bonn. EMS President Jan Philip Solovej also reported on the success of the first Indo-European Conference on Mathematics in Pune, which owed much to the work of the organisers and volunteers, and in particular to the immense commitment of Sudhir Ghorpade, co-chair of the Organising Committee.

The meeting also highlighted areas where the Society continues to renew itself. The EMS Young Academy[3] (EMYA) remains one of its most active and forward-looking parts, with a new cohort now in place, the mathematics online seminar series (MOSS) continuing successfully, and plans for further in-person activity moving ahead. Alongside this, the Education Committee under its chair Ann Dooms has launched the EMS Lecture Series on Mathematics Education, which has already attracted a strong audience both during the livestreams and afterwards on the EMS YouTube channel.[4]

[1] https://euromathsoc.org/committee-executive
[2] https://ercom.org
[3] https://euromathsoc.org/EMYA
[4] https://www.youtube.com/@EuropeanMathematicalSociety



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The palace of the Serbian Academy of Sciences and Arts in Belgrade, where the second and third days of the EC and ERCOM meetings took place.

The ERCOM meeting in session at the palace of the Serbian Academy of Sciences and Arts.

The report of the newly appointed community engagement manager, meanwhile, gave a good sense of how much work has gone into keeping things running smoothly behind the scenes, from improving continuity in the EMS communication channels to developing Good Grants workflows, supporting online events, and planning a more community-driven communication strategy for the future.

From the publishing side, EMS Press[5] reported that the baseline sustainability targets of its Subscribe to Open (S2O) model had again been met, making 2026 the third consecutive year in which all 22 EMS Press S2O journals are fully open access. The newer Launch to Open (L2O) model is now also being used to bring new or acquired journals to a sustainable level more quickly, and two journals – *Archiv der Mathematik* and *Foundations of Computational Mathematics* – are due to move to EMS Press in 2027. The EMS Magazine is likewise looking ahead, with plans for invited survey papers by ICM 2026 plenary speakers, a new AI & mathematics section, and measures intended to reduce delays in publication, including earlier editorial deadlines and the establishment of a consultant committee.

On the afternoon of 20 March the ERCOM meeting began at the palace of the Serbian Academy of Sciences and Arts. The ERCOM programme brought together presentations from research centres and several EMS committees, while also opening space for wider discussion on the role of mathematical institutes in today's research landscape. Themes ranged from interdisciplinary work and publication practices to the visibility of younger researchers and the ways in which research centres present themselves to the broader community.

One of the most interesting parts of the ERCOM meeting was the discussion on young researchers and the role of EMYA within the wider research centre network. This raised practical questions about visibility, participation, and how best to create formats that genuinely attract early-career mathematicians.

Another part of the ERCOM meeting that felt especially timely was the presentation of the new publication-awareness campaign being developed jointly by ERCOM, the EMS Committee for Publications and Electronic Dissemination, zbMATH Open and EMS Press. The campaign addresses publishing models, common misconceptions, and problematic practices in the current publication landscape, and will be deployed across the European network of research centres, with particular attention to early-career researchers. A separate article by Christophe Ritzenthaler in this issue presents the campaign in more detail.

What stays with me most from Belgrade is the sense that meetings like these are about more than reports, decisions, and agendas. Of course those matter a great deal, but so do the conversations during the breaks, the chance to meet EC and ERCOM representatives in person, and the more informal moments during the walking tour and dinner. The combination of the EC and ERCOM meetings made it easier to see both the internal work of the Society and the wider network of research centres and people around it. My thanks once again to the Mathematical Institute of the Serbian Academy of Sciences and Arts and the local organisers for their warm hospitality.

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[5] https://ems.press

# Eighty years of the Mathematical Institute of the Serbian Academy of Sciences and Arts

Marija Šegan-Radonjić and Đorđe Baralić

## From post-war beginnings to a European research hub

In the spring of 1946, in a city still recovering from the devastation of the Second World War, a small group of mathematicians gathered in Belgrade with a bold idea: to rebuild scientific life almost from nothing. Libraries have been destroyed, research has nearly ceased, and academic institutions were struggling to resume their work. Yet from these fragile beginnings emerged one of the most important scientific institutions in Serbia – the Mathematical Institute of the Serbian Academy of Sciences and Arts (MISANU).

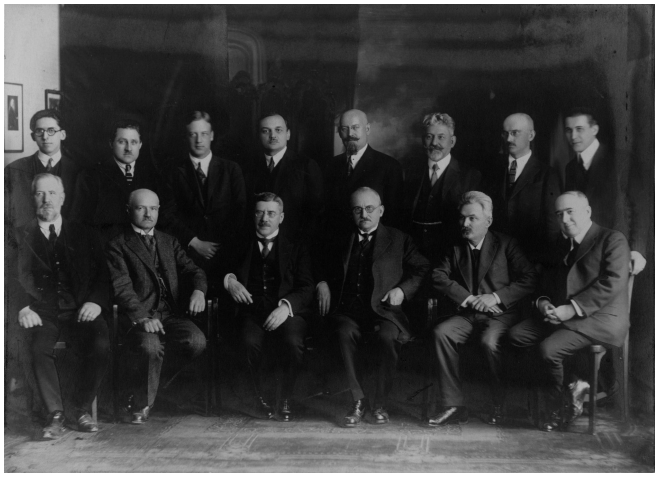
Eighty years later, the institute stands as a vibrant research centre, deeply integrated into the European mathematical community, while still preserving the spirit of its founding moment: the belief that mathematics is both a universal language and a cornerstone of intellectual and societal progress.

## Before 1946: Roots of a mathematical tradition

The story of the institute does not begin with its founding. Its roots lie in the gradual development of mathematical culture in Serbia during the 19th and early 20th centuries. Modern mathematical activity emerged through the work of scholars educated in leading European centres – Paris, Vienna, Berlin – who brought back both knowledge and academic standards.

By the early 20th century, Belgrade had developed a lively mathematical community. The informal "Club of Mathematicians" gathered university professors who exchanged ideas, presented research, and followed developments across Europe. In 1932, this circle launched *Publications Mathématiques de l'Université de Belgrade*, the first international mathematical journal in the country.

This promising development was abruptly interrupted by war. In 1944, much of the mathematical library was destroyed, and the continuity of scientific work was broken. The founding of the Mathematical Institute in 1946 was therefore not simply an institutional act – it was a deliberate effort to restore a lost scientific ecosystem.



Belgrade Mathematical School. Miloš Radojčić, Tadija Pejović, Vyacheslav Zhardetsky, Anton Bilimovič, Petar Zajankovski, Jelenko Mihailović (seismologist), Radivoj Kašanin, Jovan Karamata (standing). Nikola Saltikov, Mihailo Petrović, Pavle Popović (rector), Bogdan Gavrilović, Vladimir K. Petković (dean of the Faculty of Philosophy), Milutin Milanković (seated). (Photograph by M. Savić, 1926; SASA Archives, 14197/16)

## Founding a scientific institution in difficult times

The Mathematical Institute was established in 1946 as the first scientific institute of the Serbian Academy of Sciences. Its founders – among them prominent mathematicians shaped by both domestic and international traditions – envisioned an institution that would gather researchers, rebuild scientific infrastructure, and reconnect Serbian mathematics with the wider world.

One of the defining challenges of the early years was not a lack of ideas, but a lack of people. Most of the founders were already in their later years, and the future depended on educating a new generation of mathematicians. The admission of the first young researchers in 1949 marked a turning point, initiating a process that would gradually shape a strong and interconnected mathematical community.



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The palace of Serbian Academy of Sciences and Arts, which housed the Mathematical Institute SANU from 1952 to 2008. (Photograph by Jeremija Stanojević, c. 1930; Belgrade City Museum, UR/9527)

Rather than becoming a large institution with many permanent staff members, the institute developed a distinctive model: it functioned as a scientific hub. Many of its collaborators were university professors across Yugoslavia, while the institute provided essential infrastructure – seminars, publications, a library, and international contacts.

This model proved remarkably effective. Young mathematicians trained at the institute went on to establish departments and research centres in cities such as Novi Sad, Sarajevo, and Skopje, extending its influence far beyond its physical location.

## From classical mathematics to computing

In its early decades, research at the institute was dominated by classical areas such as mathematical analysis and mechanics. Over time, however, the scope of research expanded, following global trends in mathematics.

A decisive step toward modernization came in the late 1960s, when the institute established a computing centre equipped with an IBM 360/44, one of the most advanced computers of its time. In an era when computers occupied entire rooms and relied on punched cards, this machine opened new possibilities for complex calculations and interdisciplinary research.

Although the original computing centre was eventually discontinued due to high costs, its legacy was profound. It marked the beginning of the institute's long-standing engagement with computing, which today encompasses areas such as cryptology, machine learning, optimization, and blockchain technologies.

## Infrastructure of knowledge: library and archives

From its earliest days, the institute understood that scientific progress depends on access to knowledge. Its library, founded in 1946, grew from a modest collection into one of the most important repositories of mathematical literature in the region. Today it contains tens of thousands of volumes, including rare journals and monographs, and provides access to major international databases such as *MathSciNet* and *Zentralblatt*.

Complementing the library is the institute's archive – a rich and complex collection that documents both administrative history and scientific activity. It includes correspondence, project documentation, and records of international collaboration, offering invaluable insight into the development of mathematics in Serbia over more than eight decades.

Together, these resources form a bridge between past and present, preserving the intellectual heritage of the institute while supporting contemporary research.

## A networked institution

One of the most distinctive features of the Mathematical Institute has always been its openness. Even today, it functions not only as a physical institution but as a network that connects researchers across Serbia and beyond.

This networked character is reflected in its organizational structure. In recent decades, the institute has expanded its staff and established additional centres in Novi Sad and Niš, while continuing to rely on a broad circle of collaborators.

Research is organized into three main sectors – mathematics, computer science, and mechanics – each covering a wide range of topics, from abstract theory to applied problems. Weekly seminars, colloquia, and workshops remain central to the institute's intellectual life, fostering continuous exchange of ideas.

## International integration

From its founding, the institute has sought to maintain strong international connections.

Today, MISANU is an institutional member of the European Mathematical Society (EMS) and a member of ERCOM (European Research Centres on Mathematics), a network that brings together leading mathematical institutes across Europe.

Its researchers participate in major European programmes such as FP7 and Horizon 2020, and collaborate with institutions in more than 80 countries. International cooperation spans a wide range of activities – joint research projects, conferences, mobility programmes, and institutional partnerships.

These connections have not only enhanced the institute's visibility but also positioned it as an important bridge between regional and global mathematical communities.

## Science and society

Beyond research, the institute has played a leading role in the popularization of mathematics. One of its flagship initiatives is *May, Month of Mathematics* (M3), a nationwide programme launched in 2012 that attracts tens of thousands of participants each year through exhibitions, lectures, workshops, and public events.

The institute also actively supports young talent through educational programmes, competitions, and collaborations with schools and universities. Annual awards recognize outstanding student achievements, while outreach activities aim to make mathematics accessible to broader audiences.

These efforts reflect a broader vision: that mathematics is not only a specialized discipline but also a cultural and societal resource.

## Continuity and change

Over the course of eighty years, the Mathematical Institute has undergone profound transformations. It has evolved from a small post-war initiative into a modern research centre with global connections. Its fields of research have expanded, its infrastructure has developed, and its institutional role has grown.

Yet certain core elements have remained unchanged.

The institute continues to function as a meeting place – a space where ideas circulate, collaborations emerge, and generations of researchers are shaped. It remains committed to both fundamental research and its applications, to national development and international cooperation, to tradition and innovation.

## Looking forward

Today, the Mathematical Institute operates in a scientific world very different from that of 1946 – one defined by digital technologies, global networks, and interdisciplinary challenges. Yet the founding vision still resonates.

The institute's mission – to advance mathematical research, support young scientists, foster collaboration, and contribute to society – remains as relevant as ever.

As it enters its ninth decade, the Mathematical Institute of the Serbian Academy of Sciences and Arts stands not only as a witness to the history of mathematics in Serbia, but as an active participant in shaping its future.

From a war-torn city rebuilding its intellectual foundations to a node in the global network of mathematical research, the story of the Mathematical Institute is ultimately a story of continuity – proof that even in the most uncertain times, ideas can endure, connect, and grow into something lasting.

—

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Đorđe Baralić is a full research professor and assistant director at the Mathematical Institute SANU. He obtained a PhD in algebraic topology in 2013 from the University of Belgrade. He is actively involved in many initiatives to promote maths in Serbia and abroad. His research interests lie in the intersection of topology, combinatorics and geometry.

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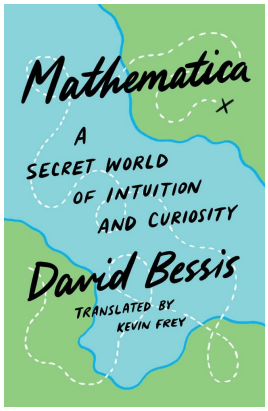
# Book review

***Mathematica: A Secret World of Intuition and Curiosity***
by David Bessis (translated by Kevin Frey)

Reviewed by Mahdi Nouraie




*You pilgrims who are on the road,*
*Where are you? Where?*
*Come back, come, the beloved is right here!*
*Your beloved is your neighbor, wall to wall,*
*You are lost in the desert! What illusion are you under?*
*– Rumi*[1]

This book explores the nature of mathematics by juxtaposing intuitive reasoning with formal logic. It interweaves biographical accounts of figures such as Einstein, Descartes, Gauss, Ramanujan, Thurston, and Grothendieck with examples of exceptional self-taught achievements, including Dick Fosbury's reinvention of high jumping and Ben Underwood's echolocation. The work challenges the conventional view that mathematical ability derives from innate talent or genetic predisposition, presenting mathematics instead as a human activity accessible through deliberate practice and sustained engagement.

From the outset, David Bessis contrasts "official math" with "secret math," arguing that mathematical texts function more as reference manuals than conventional narratives. He asserts that genuine understanding arises from internal cognitive processes not explicitly represented in such texts, which renders mathematical instruction inherently challenging. Bessis links mathematical reasoning to a form of synesthesia, the capacity to associate imagined sensory experiences with abstract concepts, and contends that effective mathematical thinking depends on the ability to "see" and "feel" abstractions rather than merely follow formal procedures. He illustrates this with examples of mathematicians, including himself, who report visual or sensory experiences of mathematical "objects."

Drawing on Daniel Kahneman's distinction between fast intuitive thinking and slow rational thinking as described in [6], Bessis proposes a "System 3," in which intuition is continuously refined through conscious reflection guided by rational thought. Within this framework, logical formalism serves as a precise apparatus for translating intuitive insight into shared mathematical language. Bessis presents this as an organic mode of human learning, characterized by mind elasticity, that distinguishes humans from computational systems. Building on this, he emphasizes writing mathematics during research, in contrast to experimental fields where reports are produced after the fact, arguing that the act of writing itself is integral to mathematical understanding, as articulating ideas precisely compels the revision and refinement of intuition.

The author observes that certain mathematical operations, such as computing one billion minus one, may appear trivial to us because we have learned to "see" 999,999,999; however, such calculations were not straightforward until the modern era. He uses this example to argue that proper education renders mathematics accessible and that operations we now perform mentally should not be taken for granted. The reviewer supplements this point with a historical perspective: concepts that currently seem intuitive, such as averaging data points to estimate the population mean, were not always self-evident. The eminent mathematician Euler, while addressing the "great inequality of Jupiter and Saturn," initially failed to recognize this seemingly obvious principle, worrying that combining data points would multiply errors rather than cancel them [5]. Later, Gauss resolved this issue in detail, demonstrating the assumptions under which errors indeed cancel when data points are combined, thereby laying the foundation for the Gaussian error law.

Bessis introduces the notion of a "child's pose," suggesting that eminent mathematicians approach problems with deliberate innocence and a willingness to ask fundamental questions, echoing the spirit of Socratic inquiry. The reviewer offers a similar perspective based on an observation at the recent Australian Statistical Education Symposium, where Linda McIver provided feedback from

[1] https://rumiroaming.subversivepress.org/pdf/rumi-roaming-ghazal-648-EN-FA.pdf

a former student: "I wouldn't be in this career if you hadn't given me the confidence to play with data like silly putty." This anecdote underscores the relevance of the child's pose, emphasizing that curiosity and intellectual freedom are vital not only in pure mathematics but also in other fields, including statistics and data science.

The primary motivation for writing this review arises from several thought-provoking statements near the conclusion of the book, which can be interpreted as a response to Galileo's famous claim that the universe is written in the language of mathematics:

> *Mathematics isn't the language of the universe. It's the language that allows us to speak with clarity and precision of all the things that we can't point to with our fingers. It's the language that makes us capable of reasoning and doing science. It's the language that's made us what we are, for better and for worse.*

This is followed by a relevant quotation from Thurston and culminates in the provocative assertion:

> *In other words, from a purely practical standpoint, math is indistinguishable from fiction.*

The earliest reference cited by the author in support of this perspective is [4]. The reviewer notes a parallel in probability theory. Although probability has intrigued humans since antiquity, it was only formally studied as a mathematical discipline with the work of Pascal and Fermat [3]. Debates concerning the nature and interpretation of probability remain active in statistics, particularly between the "frequentist" and "Bayesian" schools. The frequentist approach treats probability as an objective property of the world, estimable through experiments and observed frequencies, whereas the Bayesian perspective interprets probability as a measure of plausibility given both data and relevant prior information. Bayesian statistics has historically faced criticism for what Bessis terms the "ingrained suspicion toward anything subjective," a concern he addresses eloquently:

> *But do we really have a choice? When mathematics was just about proving theorems, it was entirely natural to treat the subjective experience as a second-rate citizen, to be covered only informally and anecdotally, if time allowed. But as soon as we realize that mathematics is ultimately about human understanding, this ceases to be an option. Understanding is, in essence, a subjective experience.*

Edwin T. Jaynes, in his posthumously published book on probability theory [5], building on the work of Pierre-Simon Laplace, Harold Jeffreys, George Pólya, and Richard T. Cox, demonstrates that all statements treated as "axioms" in both frequentist and Bayesian schools are, in fact, quantitative rules derivable from general desiderata we impose on the probability function. This perspective reframes the foundations of probability, introducing it as a consistent inference tool for logical reasoning under conditions of incomplete information. Jaynes further cautions against the "mind projection fallacy," whereby one erroneously assumes that probabilistic calculations reflect the objective properties of the world. In [5, Chapter 10], drawing on his background in physics, Jaynes argues that such physical probabilities do not exist in non-quantum settings. Historically, the Pythagoreans, among the earliest groups to study numbers, regarded them as an epistemological tool through which all things are understood, whereas Aristotle's later interpretation that things themselves are numbers became the more widely influential view in scientific discourse.[2]

These perspectives reveal two contrasting views of mathematics: one in which it serves to "discover" universal truths, and another in which it functions to "create" conceptual tools. Bessis emphasizes that the latter reflects the true nature of mathematics: even results that feel like discoveries are, in fact, discoveries of properties of tools created by human beings. From the reviewer's perspective, this distinction is especially apparent in probability and statistics, where the connection to real-world phenomena and the paradoxes that arise expose the fallacy. In contrast, more abstract branches of mathematics may obscure this point due to their greater conceptual distance from empirical experience.

In the final chapters, Bessis presents deep learning as an "effective metaphor" for human learning while maintaining a clear distinction between artificial neural networks and their biological counterparts, a distinction the reviewer considers especially important given current discussions surrounding these technologies. In this context, [7] documents the limitations of one of the contemporary large language models when confronted with elementary mathematical problems from Ancient Greece, while [1] demonstrates that human mathematical understanding engages non-linguistic brain circuits. The latter was recently highlighted by Bessis on his X account and corresponds to what he terms the "language trap" in the book. Fields Medalist Martin Hairer recently highlighted "auto-formalization" as a potential future use of large language models, illustrating this point[3]. In this light, formalism is often mistaken for an end in itself rather than a means, echoing the opening poem of this review. The reviewer also notes [2] as an excellent recent contribution demonstrating how complex mathematical concepts can be effectively conveyed without formal notation.

To conclude, the text is sharply written, with a personal tone. The book consists of short sentences, brief chapters, and concentrated reflections that are often incisive and occasionally fragmentary. Its proselytizing style and frequent bold claims may unsettle

[2] https://plato.sydney.edu.au/entries/pythagoreanism
[3] https://www.youtube.com/watch?v=fbVqc1tPLos

some mathematical readers. The reviewer considers Bessis an exceptional author and finds the book highly engaging, praised for both its wide-ranging topics and its clear, distinctive style. It is an essential read for those aiming to understand mathematics as both an intellectual practice and a lived experience, a perspective endorsed by at least two Fields medalists.[4]

David Bessis (translated by Kevin Frey), *Mathematica: A Secret World of Intuition and Curiosity.* Yale University Press, 2024, 344 pages, Hardcover ISBN 978-0-30027-088-4, Softcover ISBN 978-0-30028-328-0, eBook ISBN 978-0-30027-714-2.

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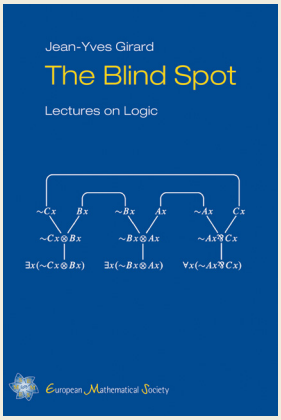
[4] https://yalebooks.yale.edu/book/9780300270884/#tab-4

## EMS Press title




**The Blind Spot**
Lectures on Logic

Jean-Yves Girard
(Institut de Mathématiques de Luminy)

ISBN 978-3-03719-088-3
eISBN 978-3-03719-588-8

2011. Hardcover. 550 pages.
€79.00*

These lectures on logic, more specifically proof theory, are basically intended for postgraduate students and researchers in logic.

The question at stake is the nature of mathematical knowledge and the difference between a question and an answer, i.e., the implicit and the explicit. The problem is delicate mathematically and philosophically as well: the relation between a question and its answer is a sort of equality where one side is "more equal than the other": one thus discovers essentialist blind spots.

Starting with Gödel's paradox (1931) – so to speak, the incompleteness of answers with respect to questions – the book proceeds with paradigms inherited from Gentzen's cut-elimination (1935). Various settings are studied: sequent calculus, natural deduction, lambda calculi, category-theoretic composition, up to geometry of interaction (GoI), all devoted to explicitation, which eventually amounts to inverting an operator in a von Neumann algebra.

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# New editor appointed

Picture courtesy of Raffaella Mulas.

Raffaella Mulas is an assistant professor of mathematics at the Vrije Universiteit Amsterdam. She obtained her PhD at the Max Planck Institute for Mathematics in the Sciences (MPI MiS) in Leipzig in 2020, followed by a postdoc at the Alan Turing Institute in London. In 2021, she then returned to the MPI MiS as a group leader, supported by a Minerva Fast Track Fellowship from the Max Planck Society, before moving to Amsterdam in 2023.

Her research focuses on graphs and hypergraphs and is supported by a Veni grant from the Dutch Research Council (NWO). Together with Jürgen Jost and Dong Zhang, she is co-author of *Spectra of Discrete Structures* (Cambridge University Press, 2026). Moreover, she is an elected member of the inaugural cohort of the European Mathematical Society Young Academy (EMYA).

Alongside her research, Raffaella is passionate about science communication and storytelling. Her outreach includes videos for *MaddMaths!* (the outreach website of the Italian Mathematical Union), popular science articles, the organization of large-scale events such as a Science Slam in Berlin, and interviews that highlight the human side of mathematics. She is the founder and chairperson of the non-profit foundation *Nora – Center for Science Communication*, the creator of a university course on storytelling and science communication, and the author of *Stories Behind Theorems* (Springer, 2025). She has performed at storytelling events across Europe and gave a TEDx talk titled *Dancing out of the Box* on stereotypes affecting the mathematics community and women in STEM. For the EMS Magazine, she curates *Side by side*, a series of double interviews with mathematicians.



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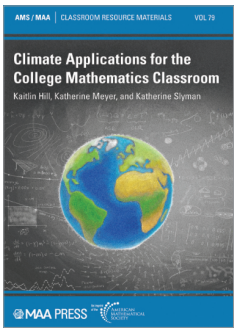


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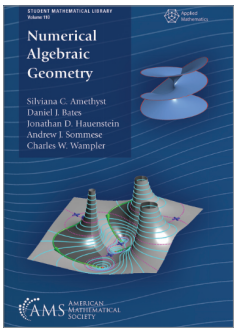


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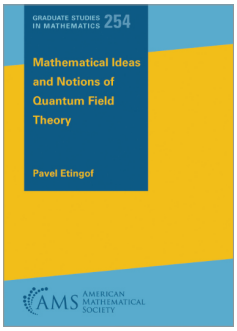


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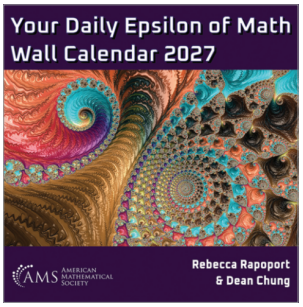


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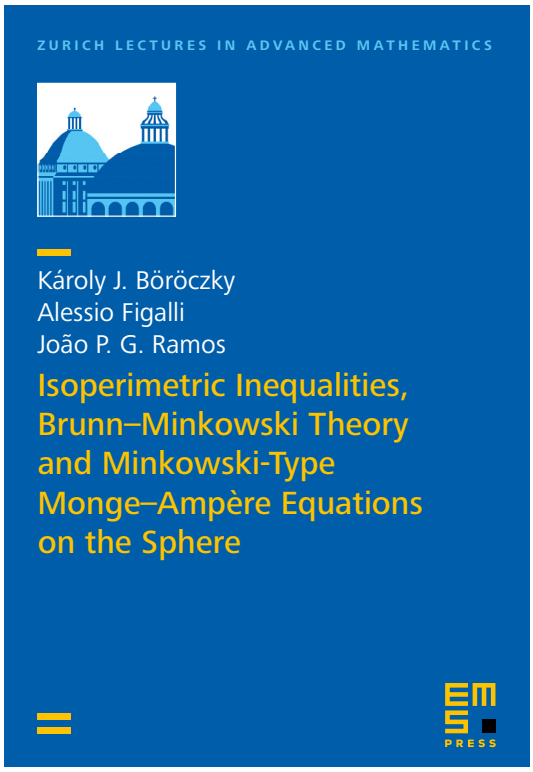


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