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EDITORIAL

The ICMAT recognized for the third time for excellence

Image: ICMAT

Diego Córdoba

The definitive resolution of grants for the Severo Ochoa Center of Excellence distinction to the ICMAT and nine other Spanish research centers was decided in December of last year. This is the third year running that the Institute has received this recognition and it is the only CSIC center to have been honoured in this way. This distinction is the result of the outstanding track record shown by the ICMAT, a center whose management, activities, obtention of competitive projects – especially those awarded by the European Research Council (ERC) – and its scientific results over recent years have hallmarked it as one of the leading mathematical research centers in Europe.

The two previous Severo Ochoa projects made a profound impact on the scientific life of the Institute, strengthening its internal structure and consolidating its different scientific programmes, which together have successfully helped to generate and attract mathematical talent to the center. Among these, we may mention the Severo Ochoa Laboratories, headed during the second project by Kari Astala (University of Helsinki, Finland), Ignacio Cirac (Max Planck Institute of Quantum Optics, Germany), Simon Donaldson (Imperial College, United Kingdom; and Simons Center for Geometry and Physics, USA), Nigel Hitchin (Oxford University, United Kingdom) and Charles Fefferman (Princeton University, USA).

In addition, throughout this time the ICMAT has pursued an intense scientific activity that has earned it a much greater visibility on the international stage; between 2015 and 2019, the center has welcomed approximately 750 visitors, hosted more than 700 seminars, 42 colloquies and 18 schools, as well as holding 65 workshops and conferences and nine thematic programmes.

Furthermore, funding through the Severo Ochoa projects has cemented cohesion between the different institutes with representation at the ICMAT, particularly thanks to the grants for PhD programmes and joint seminars. This has also strengthened the leadership of the Institute in the field of mathematics at both a regional and a national level.

We now eagerly embark on this new phase with the determination not only to maintain but also to improve on the work undertaken in previous years. To that end, we have at our disposal an annual funding of one million euros over the next four years, and an endowment of 14 predoctoral contracts as well as the option to participate in post- and pre-doctoral programmes offered by La Caixa Foundation.

Although 2020 has been an exceptional year during which activity at the center has been drastically reduced due to health reasons, I am convinced that we can make the most of the new Severo Ochoa programme to enable us to get back up to speed with activity here at the Institute. We will be running predoctoral programmes (such as the master grants, the contracts associated with Severo Ochoa and those of the FPI type, as well as "La Caixa" and the JAE School); post-doctoral programmes (with the launch of nine two-year contracts, as well as the possibility of opting for La Caixa programmes). Furthermore, we will continue with the laboratory programme and that of stays by distinguished professors, as well as the seminary, colloquium, congress, workshop and school programmes and thematic and visitor programmes.

Likewise, the Severo Ochoa project also bolsters knowledge transfer, and of course the proactive popularization policy conducted in previous years, the aim of which is to raise the profile of mathematicians in society and to increase the number of students and women engaged in mathematics.

Diego Córdoba is the Scientific Director of the Severo Ochoa project at the **ICMAT.**

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REPORT: Black Holes: When mathematics illuminates what cannot be seen

The work by Roger Penrose on the prediction of the existence of black holes has earned him the 2020 Nobel Prize in Physics. In particular, the jury emphasized the mathematics that made it possible to show that, where the general theory of relativity acts, these invisible bodies must necessarily exist. The theories that Penrose published in 1965 have been experimentally verified by Andrea Ghez and Reinhard Genzel, who were jointly awarded the Prize for discovering a super-massive object at the very centre of our galaxy. First the theorem and then the evidence to uphold it. Mathematics has acted as a spearhead for physics by pointing out what was impossible to see. And it is mathematics that has been the vital tool throughout more than two centuries for this exotic celestial body to be taken seriously, as well as being the cutting edge towards resolving the many unknowns surrounding black holes.

Elvira del Pozo

We know that a black hole is a region of the universe with a gravitational field of such magnitude that no light is able to escape from it, and thus is completely impossible to see. Just as a pile of rubble marks the spot where a large building once stood, so black holes appear to have once been gigantic stars that collapsed in on themselves due to their great mass. They also conceal a secret; exactly at their centre quantum mechanics and gravity act in conjunction with each other – the dream of the grand unified theory of physics made a reality!

Mathematics tackles this and many other unknowns in the attempt to be once more the pioneer that leads to their resolution. More than 50 years ago, mathematics convincingly showed for the very first time that such exotic celestial bodies existed, a discovery that has now been distinguished with the 2020 Nobel Prize in Physics.

However, the story of black holes goes back a very long way. Although they are associated with Einsteinian physics, already in 1783 the clergyman, geologist and astronomer John Michell made a theoretical prediction about their existence. "If there should really exist in nature any bodies, whose density is not less than that of the sun, and whose diameters are more than 500 times the diameter of the sun, any light emitted by this body would turn back towards it under the effect of its own gravity… and would never reach us," he explained in one of his articles. These "dark stars", as he called them, since they could not be seen, are the Newtonian precursors of black holes. Michell also proposed a means of detecting them in those cases where they formed binary stellar systems with visible companions, so that the gravitational influence of their hidden neighbour would be detectable through the behaviour of these visible companions.

Likewise in the late eighteenth century, in 1796, the French mathematician Pierre-Simon Laplace put forward the same idea. "There are in the heavens dark bodies perhaps as large and numerous as the stars themselves." After that, silence: the scientific community regarded such proposals as too extravagantly exotic to merit any serious consideration; until a century and a half later when Albert Einstein appeared.

A model for everything

In 1915, Einstein conceived of a universe in which all objects are suspended in a space-time network consisting of four dimensions (three of space and one of time) curved by the effect of gravity and which created mass and energy. Space-time ceased to be a simple scenario and became the principle factor responsible for the movement of bodies. Thus a star made planets follow the deformation that the star itself caused in the network that sustained them all, akin to a ball spinning in a roulette wheel.

The entire grand-scale physical world was then described by the general theory of relativity, a mathematical model consisting of a system of ten nonlinear partial differential equations linking together the curvature of space-time with the matter responsible for gravitational attraction. Einstein thereby corrected the errors in the Newtonian explanation that until that time had held sway, according to which, for example, between the Earth and the Sun there was an invisible tie that kept the former rotating in orbit around the latter. However, Einstein had time only to sketch out this grand design and was unable to provide any exact solution. Obtaining numerical values for which the mathematical equality holds true is so enormously difficult that only a few hundred solutions are known to date.

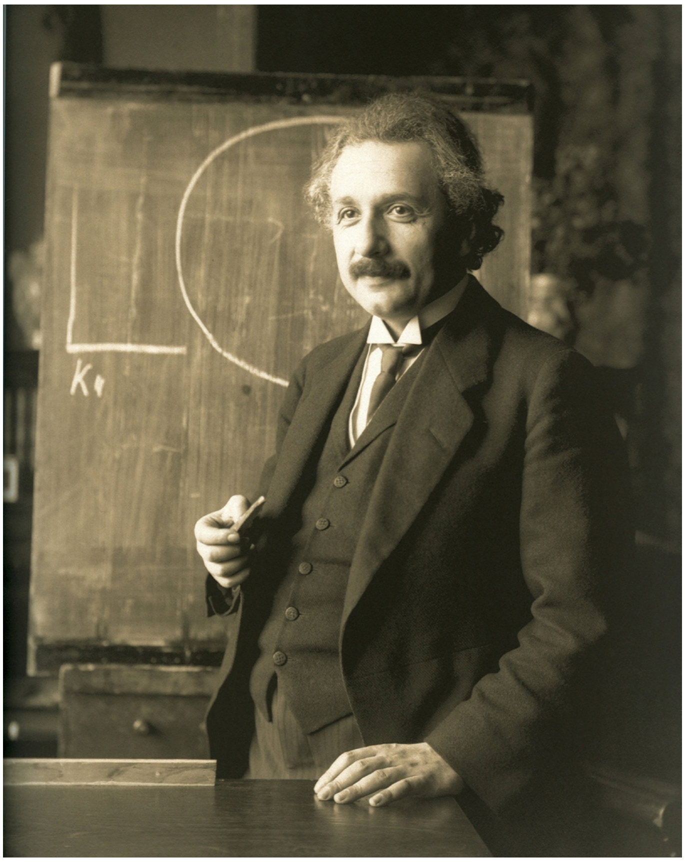


Image: Ferdinand Schmutzer, via Wikimedia

Einstein, six years after publishing the theory of relativity.

Since then, mathematicians have been working to find these solutions with some remarkable, albeit only partial, success. As ICMAT researcher Albert Enciso explains: "It is a strongly geometric theory, and understanding it requires tools of differential geometry, as well as in more recent times partial differential equations." It is also necessary to take into account that "relativity involves aspects both classical and quantum, the latter being so far insufficiently understood mathematically," he points out.

From the trenches

The same year in which he published his ground-breaking findings, Einstein received two letters from the front line during the First World War. They were sent to him by the physicist and mathematician Karl Schwarzschild, already seriously ill, from his bed at a field hospital. In these letters he proposed the first non-trivial solution to the general theory of relativity. Known as the Schwarzschild metric, in it he describes the space-time and the gravity generated by a star or a perfectly spherical mass, and also for a black hole if it fufils certain conditions. Schwarzschild assumed that if the mass of a star was very great and was compressed into a smaller and smaller volume, the space-time region surrounding it would also become increasingly curved until it finally became a bottomless pit from which nothing, not even light, could possibly escape. In such cases, it is reasonable to assume that a black hole would be formed.

The reason why spherical corpuscles were chosen as the object of study was to simplify the resolution of the equations. As Enciso explains: "The usual approach is to treat the body like a point particle, without charge and assuming it to be static, which relieves you of many headaches because even today we still have many basic mathematical problems that remain unsolved when black holes are not static." This enabled him to obtain a solution but complicated its recognition.

Mathematically, Schwarzschild found that surrounding very small massive bodies a region exists where the metric involves no difficulties, and another where the interpretation of the solution is more complicated. The transition surface between these two regimes is given by the event horizon, and at the origin a singularity exists where the curvature explodes," says Enciso.

While the scientific community and Einstein himself praised Schwarzschild's solution, they thought it improbable that perfectly spherical stars could really exist in nature, and therefore ruled out the possibility of the existence of such dark corpuscles. Indeed, if they were to exist it would be difficult to prove their existence because they would be invisible. Schwarzschild died at the front in 1916 at the age of 42.

In 1930, the physicist Subrahmanyan Chandrasekhar suggested that stars with a mass of more than 1.5 times the mass of our sun would collapse in on themselves due to the action of gravity, thereby shrinking down to something extremely dense. Nine years later, in 1939, the North American theoretical physicist Robert Oppenheimer developed a model of collapse by which he proved that an ideal body with a perfect symmetry would collapse in on itself indefinitely. This is what would happen with massive stars on completion of their thermonuclear processes.

Another point of view

In 1963, the New Zealand mathematician Roy Kerr generalized Schwarzschild's metric to a non-static rotating body. Two years later, the Kerr-Newman metric extended the theory to charged corpuscles. These solutions provided the foundation for the existence of black holes, now also in motion, but still arising from perfectly spherical stars.

Around that time, the physicist and mathematician Roger Penrose was wondering if he could somehow get round the hypothesis of perfect spherical symmetry. "What had been done up until that time was to solve complicated equations, and that's not a very good idea if what you want to do is to introduce irregularities, because then quite simply you can't solve them," he explained in an interview in 1999 with mathematician and physicist and member of the ICMAT, Oscar García-Prada, for the journal *Gaceta Matemática*. So he approached the problem, as he went on to say, "from a completely different point of view, which consisted in looking at general questions; basically questions of a topological type that enabled one to arrive at a contradiction of the hypothesis from which collapse without singularities would take place."

As García-Prada explains: "Penrose used tools from global differential geometry, a branch combining geometry with calculus, and taking into account topological questions. Not only does one study what occurs close to a point, but also what happens to the elements of space in its entirety." For example, in the case of analyzing the surface of a ball and that of donuts, when observing only what happens in the neighbouring region of a certain point in both areas, the behaviour is indistinguishable; however, globally they are very different.

So in 1967, together with Stephen Hawking, and on the basis of Einstein's relativity equations and using techniques of mathematical analysis and differential topology, Penrose demonstrated that it was not necessary to assume any symmetry in order to obtain the solutions corresponding to black holes. By means of a mathematical theorem (the Penrose singularity theorem) he showed that collapse would occur, and therefore black holes would be formed under particular fairly general conditions.

Image: Aitor Rodríguez

Roger Penrose in 2011

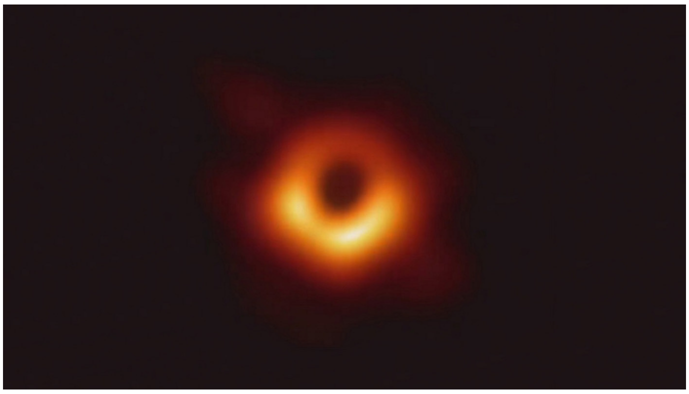


Image: Collaboration of Event Horizon Telescope

First photography of a black hole, taken in 2019

Some years later, Hawking suggested that black holes were perhaps not quite so black, because they emitted radiation (Hawking radiation) beyond the event horizon as a consequence of quantum processes. For that reason, the black hole would continue to lose mass until it evaporated entirely. This famous physicist also published a second great theorem on singularities using the tools that Penrose had employed, and demonstrated that another space-time singularity would have given rise to the origin of the universe.

As Enciso explains: "The enormous contributions made by Penrose and Hawking's theorems is that by means of extraordinarily simple reasoning, with symmetries, they proved that, given conditions of positive energy and if the causal structure of space-time is reasonable (referring to the grandfather paradox, whereby you cannot travel back through time and kill your own grandfather before you were born), it seems right to believe that singularities are commonly formed in space-time."

Both singularity theorems "are part and parcel of the same package expressing that space-time is geodesically incomplete," says García-Prada. This suggests that at some juncture space-time will come to an end.

For his proof that the formation of black holes can be deduced directly from Einstein's theory of general relativity, Penrose was awarded the 2020 Nobel Prize in Physics, although as García-Prada remarks, "it's a prize for mathematics itself, and differential geometry in particular."

The evidence

In one of the first interviews that Penrose gave after learning that he had been awarded the prize, he was asked whether he thought that if Hawking was still alive he would also have been awarded it, in this case for his Big Bang singularity theorem. Penrose' answer was "possibly not." García-Prada is of the same opinion: "Although experimental evidence exists for black holes – in part thanks to the work by Reinhard Genzel and Andrea Ghez, the other two winners – there is none for the Big Bang."

As expert in applied physics in astrophysics and cosmology, and founder of the Spanish Astrobiology Centre, Juan Pérez Mercader said in an interview: "Coming up with theories is easy insofar as it's basically words on paper, and the models you can write are more or less consistent, but what you need is evidence." In the end, as García-Prada points out: "This Nobel Prize is a combination of mathematical work done 55 years ago and physical experimentation confirming the mathematics."

Open problems

"The most important mathematical problem we have regarding black holes is the cosmic censor hypothesis, which is also due to Penrose," says Enciso. There is a hypothesis in these singularity theorems that still remains unsubstantiated: cosmic censorship. Penrose believed that the reason why we cannot see the singularity at the heart of the black hole is that it is covered and hidden by the event horizon, which prevents any information from coming out. As this researcher says: "Naked singularities are more aggressive than black holes for any observer." The general consensus is that generically they should not occur.

A further unknown concerns what might happen within a black hole. It appears undoubtable that it is a zone where there is a great deal of matter occupying a very small space, and where quantum interactions hold sway. One consequence of the existence of singularities demonstrated by Penrose is that "it marks the point where another type of physics is required, where quantum theory meets general relativity and where they act together, because it is there where things are at once small and massive," according to what he explained to García-Prada. The problem is that both theories contradict each other. "It's not about quantizing general relativity, gravity and space-time," added Penrose. "A new theory is required – quantum gravity." The solution is far from evident and gives rise to much controversy. Furthermore, it is a subject about which he and Hawking held different opinions. As Enciso adds: "Mathematics is currently unable to tackle quantum gravity; we don't even know how to do it with normal quantum field theories."

Enciso goes on to say that there are "stability problems, how to determine whether Kerr space-time is stable or not. There's a mathematical theorem that, according to certain hypotheses, tells us which stationary black holes exist, but we don't know what happens if we disturb them a little", Enciso says. "Another factor is that physicists have spectacular images of how two black holes could fuse together, but mathematically we don't know how it might happen."

"Many of these problems connect with different areas of mathematics, such as dispersive equations, harmonic analysis, geometric analysis and complex geometry, all of which are extremely interesting," concludes Enciso.


Image: Courtesy AIP Emilio Segrè Visual Archives, via Wikimedia

Karl Schwarzschild in his office at Postdam (Germany)

INTERVIEW: Martin R. Bridson, professor at Oxford University, president of the Clay Mathematics Institute and member of the ICMAT External Scientific Advisory Committee

"Everyone thinks they won't prove anything as a graduate student"

Martin R. Bridson is one of the leading lights in geometric group theory, which consists of a combination of algebra, geometry and topology. He entered this field when it was just emerging and he was still a PhD student at Cornell University (USA), inspired by Mikhael Grómov's work. Over the years he helped to lay the foundations of the theory as well as solving important problems in this and other adjacents fields. During the last 15 years, his passionate pursuit of new mathematics has led him to focus his attention on profinite groups. Bridson holds the Whitehead Chair of Pure Mathematics at Oxford University (UK) and is also the head of the Clay Mathematics Institute, which enables him to remain abreast of the latest developments in the discipline. Among his most notable distinctions are the Whitehead Prize from the London Mathematical Society (1999), the Wolfson Research Merit from the Royal Society (2012) and the Steele Prize from the American Mathematical Society (2020). Furthermore, he is one of the eight members of the ICMAT Scientific Advisory External Committee. In November we had the opportunity to talk to him via video call, a medium he believes will help to contribute to the democratization of mathematics.

Ágata Timón García-Longoria

When and how did you become interested in mathematics?

I was naturally always interested in mathematics. I loved mathematics in school. It was clear to me that things that appeared obvious to me in mathematics didn't seem obvious to other people, so I understood that maybe I was good at it. From the age of 15-16, I was eager to learn as much mathematics as I could, so it was logical that I opted to study Mathematics at university. I didn't realize that I would be attacted to research in mathematics until I was much older, because I had no examples of the life of a researcher, I didn't know anybody who had worked at a university. Coming from a working-class environment, I simply imagined that I would study Mathematics and get a good job in an office and lead a normal life. It was only halfway through my undergraduate course that I envisioned the possibility of mathematics as a way of life. I understood how vast mathematics is, and how quickly you come across open problems. So it was a natural step to take up research in mathematics. After all these years, I am very glad that I became a mathematician, and mathematics continues to excite me.

Why did you decided to move to Cornell, to the USA, for your doctoral studies?

I always wanted to travel the world, and I became aware that in America you can get a teaching assistantship while doing a PhD, so you didn't need any money to do a PhD in America. So I applied for scholarships and teaching assistantships in USA, although I did so quite late on. I didn't really decide this until the spring of my final year as an undergraduate student, so most of the deadlines had already passed. I talked to people in Oxford and they suggested a list of places where people were doing the type of mathematics I was interested in at the time. I wrote to them, some of them wrote back, and one of those people was Jim West at Cornell university, and he invited me to go to there.

What kind of mathematics were you interested in at that time?

A combination of functional analysis and classical topology, something called Hilbert cube manifolds. West had proven a great theorem about Hilbert cube manifolds. But when after I arrived at Cornell my mathematical interests changed a lot. I met a lot of interesting people doing a new type of mathematics that I hadn't come across before: low dimensional topology. I realized that the most exciting things that were happening at that time were in that field.

What do you remember about this early period of your career?

It was very exciting. First of all, learning about low dimensional topology and mapping class groups. I was highly influenced by Andrew Casson's lectures notes on automorphisms of surfaces, and that got me interested in the role of groups in low dimensional topology. For me, interesting groups have to appear in topology, as do the fundamental groups of spaces and symmetry groups of geometric objects. Also, reading William Thurston's notes on three manifolds was also a very event important for me. And then I very much admired the work of John Stallings, who was one of the founders of modern geometric group theory. Subsequently I became a student of Karen Vogtmann, who was studying automorphisms of free groups, and again, motivated by comparisons to low dimensional topology and geometry.

> "Mikhail Gromov's essay 'Hyperbolic groups' was a turning point in my life"

Those were the beginnings of geometric group theory; how did you get interested in the field?

At that time the subject of geometric group theory didn't exist, it didn't even have a name. People talked about topological methods in group theory, and Stallings was the leading figure. But it was just at that time when Mikhail Gromov wrote his es-

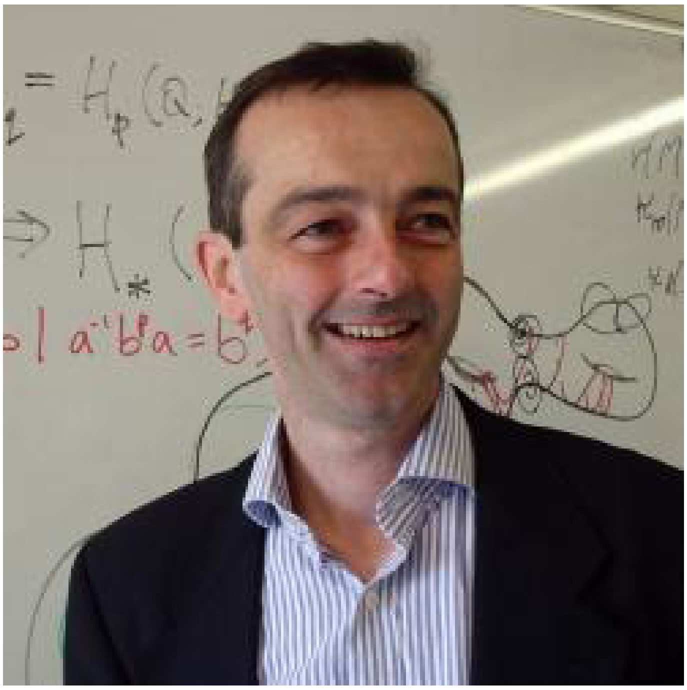


Image: University of Oxford

Martin Bridson is a member of the ICMAT External Scientific Advisory Committee.

say "Hyperbolic groups". Vogtmann suggested that I read it, and that really was a turning point in my life. I spent a year studying this essay, trying to understand it. It was like nothing I'd ever read before, a paper full of inspiration. It has many more ideas than proofs, and many details are missing, so at the beginning I found it very frustrating and it made me feel very stupid. But when I started to understand it I was very inspired by it. A large part of my thesis is devoted to sorting out one page of this essay, where he says that some things were well known and easy to prove. Well, it turned out that they weren't so well known, and they weren't true in the way he stated it. However, if you adjust the hypotheses, they were true. The idea was true, but the details were wrong. That was my first theorem.

What was this first experience of mathematical research like?

It was a bit scary: the fear that nothing would work out. That's something I try to convince my own graduate students about. I think everybody I know —and this was certainly true for me— have experienced that feeling as graduate students; that maybe things won't work out. You're afraid that you won't be able to prove anything. You might be good at learning mathematics, but that doesn't mean you can create mathematics. But I was still very much in love with mathematics, so I found it very exciting. I think it's really important to remain excited about mathematics at every stage of life, but particularly as a graduate student.

"If you recognize negative or non-positive curvature and you make the correct definitions, you can exploit it to prove interesting things"

Your first theorem had quite an impact.

Yes, it was really a great boost that kept me going. And it was a great point of departure for me, because Stallings and André Haefliger were both interested in whether this particular fact was true or not: the existence of geodesics in locally infinite simplicial complexes. They were both interested for reasons to do with group actions and group theory.

What kind of problems motivated the beginnings of geometric group theory?

You really see a lot of the ideas in modern geometric group theory in the papers by Poincaré and Max Dehn. There are many things in Poincaré, but the connection between the fundamental group and hyperbolic geometry is really important in Dehn. And also the idea that classical hyperbolic geometry could be studied by the groups themselves, and that it can be done in large classes of groups. Dehn was the person who recognized the importance of algorithms regarding whether you could decide things about groups. For example, Dehn really wanted to classify knots, and he understood that classifying knots could be translated into a problem of the fundamental group of the knot. He wrote these fantastic papers explaining how solving these problems about knots would lead to the solvution of presented groups, and that these were fundamental problems about finitely presented groups.

So how did modern geometric group theory start?

Alfred North Whitehead, and then Stallings, thought about automorphisms of free groups in topological terms, and that was very important. And then Gromov came along. He had original ideas, but he also grew up in the St Petersburg school of geometry, with Pavel Alexandroff. So he came up with all of these ideas about metric geometry, and many more ideas from differential geometry, and he combined them. He saw how naturally the classical ideas of Dehn and Poincaré fit in with Russian school of metric geometry; in particular, the importance of curvature, negative or non-positive. You can find this in Dehn, but it was really Gromov who focused on it. Gromov's essays constituted the establishment of group theory, or rather topological group theory, as a real subject, in the sense that it became a real theory posing big questions. He gave it much more structure, so it went from being a few beautiful scattered, disorganized things to an authentic, coherent theory.

You have also been interested in negative and non-positive curvature. How does this concept appear in your work?

One of the themes that has always interested me is the way in which negative or non-positive curvature emerges naturally in all sorts of settings where you wouldn't expect it. If you recognize that and you make the correct definitions, you can exploit the presence of curvature to prove interesting things. For example, you can check the conditions locally, on a small scale, and deduce that they are true on a big scale. It is a powerful way of thinking that allows you to solve problems that in the first instance didn't appear to have anything to do with negative or non-positive curvature.

How do you understand negative curvature?

I first encountered curvature on a differential geometry course, where you do calculations with tensors and so on. I was able to do that, but I didn't have a clear idea of what curvature was. I think that a much better way to tackle curvature is first to learn hyperbolic geometry in a classical sense; by drawing lines and triangles and calculating areas, and understanding what it feels like to walk around in hyperbolic space. You imagine yourself standing in a space and you look along two rays of light; curvature tells us how quickly those diverge. If you are in a Euclidean space, two lights coming out of a point diverge linearly, whereas on a sphere –that has positive curvature– they diverge slower than linearly. In spaces with negative curvature, rays of light diverge very quickly. Another way to see this is that geodesic triangles are extremely thin. Also, if you take a loop and fill it with a disk, the area of the disk can be bounded by a linear function of the length of the loop, whereas in Euclidean spaces the function will be quadratic. In different contexts, if there is negative curvature you will find some manifestation of these three properties.

"I have been interested in making a negative or non-positive curvature spaces theory as rigorous as possible"

And non-positive curvature?

Roughly speaking, non-positive curvature is when you allow some Euclidean behavior and negative behavior, and that means, crucially, that you can take cartesian products of things.

What are your main contributions to the subject?

I have been interested in two things. The first concerns the foundations of the subject, how to make the theory as rigorous as possible. Twenty years ago I wrote a book with Haefliger about spaces of non-positive curvature, with the aim of making many things precise and providing a clear treatment, so that people could learn about non-positive curvature and use it. I really think about the foundations. And the second thing is the creation of techniques for building interesting new spaces, which I could use to answer questions about groups. For example, I tried to answer many questions about groups by getting those groups to be the symmetries of non-positive curved spaces. I'm very interested in which groups act as symmetries in non-positive curved spaces.

Group theory is the language of symmetry. Why is symmetry so important in mathematics?

I think there are two main reasons: the beauty of the symmetrical objects and the power of being able to use symmetries to simplify complicated things; for example, to transform infinite problems into finite and manageable problems. If you have an infinite object and you know that some finite fundamental domain can be translated by the symmetries to cover the whole infinite object, then you can just study this finite piece, together with the symmetries, to understand the total space. The key then becomes understanding the system of symmetries, which will be coded as a group. This is why group theory is so central to so much of mathematics.

You also have a long-standing interest in algorithms in group theory and geometry. Can you tell us about that?

I want to understand precisely what it means for a problem to be hard, and for that you need to know how you quantify the difficulty of a solution. This forces you to understand the objects in a much more exact way. For example, above dimension 5, there is no algorithm that, when given a finite description of a compact manifold, can tell you whether it is homeomorphic to a sphere. In principle, we think that we know what a sphere is, but in fact we can't recognize it, so we don't know really what a sphere is.

"One of the great things about geometric group theory is that it connects different fields of mathematics"

In recent years there have been spectacular advances in the field of geometric group theory. Could you mention any?

One of the great things about geometric group theory is that it connects different fields of mathematics; it has become such an important field because it also solves fundamental problems in other fields. A great example of this is the interaction with the theory of three dimensional manifolds. In particular, the work by Ian Agol and Daniel Wise proves that every hyperbolic three-dimensional manifold has a finite sheeted cover which is a surface bundle over the circle. This was solved by translating it into problems about geometric group theory, particularly, building CAT (0) cube complexes. I would also like to mention the great work by Frédéric Haglund and Wise with CAT(0) cube complexes. These are objects that I thought about since I was a graduate student, and Wise, who was my student, has done outstanding work with them.

So far, you have had 14 PhD students. Is it important for you to have PhD students?

Yes. I think it is very important to spend time with graduate students and pass along ideas. Every mathematician has many more ideas than they have time to write about in papers, so it is important to pass them on so other people can work on them.

What are the challenges in the field? What remains to be done?

There are many great challenges. Although we now know a great deal about hyperbolic groups, we still don't know if they are all residually finite, and this is an important question. And the question about whether essentially all hyperbolic groups have surface subgroups is also a big problem. I used to think that the answer to both of these questions would be negative, but recently it has been shown that huge numbers of hyperbolic groups are residually finite, and that huge numbers of hyperbolic groups do have surface subgroups, which suggests that there is something really deep going on.

Another great question –in a completely different direction– is whether all finitely generated groups are sofic. Again, the answer to that question should be no, but it is surprisingly hard to construct counterexamples, which again points to something very deep going on.

Are you working on any of those problems?

For me these problems are in the background. At the moment I'm very interested in profinite rigidity, thus the extent to which groups of geometric interest are determined by their finite images. I'm interested in that because it brings in a lot of different sorts of mathematics and requires a deeper understanding of many different sorts of objects.

In the recent years you have been working on profinite groups. Why did you decided to focus on this subject?

Initially I got very interested through a collaboration with Fritz Grunewald. Grunewald explained to me these problems of Grothendieck from algebraic geometry. Profinite groups also have roots in geometry, but they are an entirely different sort of group theory from the one that I've been studying before. You need different types of mathematics to understand profinite groups, so it was an opportunity to learn about a new type of mathematics.

What specific problems of profinite groups have interested you?

I got very interested in the question of the extent to which understanding all of the finite quotients of an infinite group will tell you what the infinite group is. This is a natural problem from an algebraic point of view, but it is interesting because it brings in all sorts of different mathematics. And it connects to a lot of exciting work that has been done in low-dimension topology in recent years, which is connected to the understanding of how you construct finite sheeted covers of compact spaces, or said another way, understanding the finite index groups of a given group. You'd think that these two problems –understanding three-dimensional manifolds, for example, and understanding the finite index subgroups of groups– are entirely unrelated, but they are not. They are fundamentally related. To solve this problem –which didn't seem to have anything to do with non-positive curvature– I used a lot of things I'd developed about non-positive curvature. In some ways, everything that I'd been thinking about until then was used in the solution.

"I think it is very important to spend time with graduate students and pass along ideas"

You have also held leadership and management roles at leading mathematics research centers, first as director of the Oxford Mathematical Institute from 2015 to 2018, and now as a president of the Clay Mathematics Institute. What have you learned from these experiences?

We all become mathematicians because we love doing mathematics, but we need structures to make sure that there are opportunities to do mathematics in the future. I think it is important that people who love mathematics undertake these leadership roles to ensure that the subject is addressed. Having said this, while there are many frustrating things about running an institute, there are many rewarding things as well, like the opportunity to understand other areas of mathematics and acquire an overview of the field. You have to know where the most exciting breakthroughs are taking place, and what is important for the evolution of mathematics at the time. As the director of the Oxford Institute, I was able to acquire a greater appreciation of the many exciting things that are happening in applied mathematics. That it is not something I would have seen clearly if I'd just remained a professor of pure mathematics.

"As a director of an international institute you have the opportunity to acquire an overview of the field"

What would you say has been your main contribution to these institutions?

When I was head of the institute in Oxford, we started a free-standing master's program, which enabled us to bring the best students from around the world to Oxford, whereas previously our advanced courses were open only to our own undergraduates. A further important thing concerned the hiring decisions I was able to make. And another thing is to encourage the conversation between pure and applied mathematics, to transmit the vision of mathematics as one continuous subject, going from foundations to immediate applications. At the Clay Institute, the most important thing is to be able to support the very best of mathematics, without any national or political concerns. For that, we need mechanisms that recognize excellence wherever it may be found in the world, and provide the resources to do so.

How has the COVID-19 pandemic impacted on the Clay Institute program?

Many of our traditional activities, such as funding conferences, are being cut back due to the pandemic. But now I see a lot of new opportunities for extending excellence in mathematics to new communities of people, because we all have learn to communicate mathematics remotely. A person in any country can now very easily give a seminar in a university in any other country. We can also put in place mechanisms for high level researchers to guide research groups in countries that don't have a lot of resources to fund fundamental mathematics.

Other than that, how do you think the COVID-19 crisis is going to affect mathematical research?

I think we'll be travelling less. The seminars will never entirely restrict speakers from the room, but also speakers from anywhere else in the world. The great advantage of this is that everyone will have direct access to the most exciting contemporary conversations and the most important ideas of the moment in mathematics I think there'll be a democratization of mathematics. On the other hand, however, I think the importance of getting together, and the casual interactions of a conference, will remain. So it will still be important to hold physical conferences, although I think we'll have fewer of them.

SHE DOES MATHS: María Xosé Rodríguez-Álvarez, Ikerbasque Research Fellow at the BCAM

Research fields: Statistics Applied to Biomedicine and to Agriculture.

Laura Moreno Iraola

"I decided to devoted myself to statistics because it's one of the branches of the mathematics with the most direct applications to a wide variety of situations and different areas. What I was looking for was the opportunity to apply what I studied to solving problems in the real world," says María Xosé Rodríguez-Álvarez, Ikerbasque Research Fellow at the Basque Center for Applied Mathematics (BCAM) in Bilbao.

In recent years, the problems she is referring to have mainly been in the field of agriculture, and it is precisely in this context that she has developed one of the results of which she feels most proud. In collaboration with researchers at the University of Wageningen (The Netherlands), she set up a project, still active, for what she explains as the "development of new statistical methods and spatial models to determine how much of the behaviour observed in a field experiment can be attributed to genetics and how much to the surroundings and the environment, so that the selection of the best vegetable varieties, ranging from those producing most grain to those most resistant to disease, can be assured. It constitutes an important step forward for many agriculture manufacturing companies that base part of their business on the development and commercialization of new crop varieties, a process known as "genetic improvement."

"I know that many companies are using the technique we have developed, called SpATS, to analyze their experiments," says Rodríguez-Álvarez. She goes on to point out that its impact is due mainly to the development of software that enables the technique to be used and applied quite straightforwardly in different contexts. These programmes enable the time between the development of a new statistical method and its practical application in the real world to be shortened.

The researcher is currently working with massive data from high spatial and temporal resolution field experiments, which are obtained by means of the so-called high-throughput phenotyping platforms, thanks to which the behaviour of varieties can not only be measured and recorded throughout the experiment, as is done traditionally, but also at many different points in time during the development of this behaviour. The main challenge posed now is the development of new statistical methods and software to enable an accurate analysis of this information. The methods must be computationally efficient in order to process such a large amount of this data, in addition to being able to be implemented on any personal PC as well as obtaining the results in a short period of time.

Rodríguez-Álvarez has also conducted research into statistics applied to the field of biomedicine in areas such as the development of new methods for evaluating the diagnostic value of clinical biomarkers. Moreover, in collaboration with Francisco González, a professor in Ophthalmology at the University of Santiago de Compostela, she has studied neural activity in the visual cortex, that is, the region of the space that elicits a response in the neurone. As a result of this work, and on the basis of the data obtained by González from his experiments, they have together arrived at a new method for estimating of this visual receptive field, which possesses spatial and temporal characteristics that it was necessary to take into account.

Image: María Xosé Rodríguez-Álvarez

María Xosé Rodríguez-Álvarez is Ikerbasque Research Fellow at BCAM (Bilbao).

Furthermore, during her time spent between 2010 and 2013 on biostatistics at the Hospital of Santiago de Compostela, the researcher participated in projects concerning tumour biomarkers, factors associated with worst-case prognosis of heart disease and morbimortality in premature births. Analysis of the data collected was aimed at answering questions such as whether a new tumour biomarker was reliable or whether anaemia or bleeding constituted a risk factor.

Likewise, Rodríguez-Álvarez has also been engaged in the evaluation of diagnostic tests, such as PCR and seroprevalence tests that are currently used to detect COVID-19. Before a diagnostic test can be routinely rolled out in clinical practice, it is necessary to estimate its precision; that is, to validate statistically whether the test is reliable and useful, the latter being dependent on the context in which it is to be applied. Rodríguez-Álvarez is developing statistical methods to evaluate such diagnostic precision and to study whether a test changes in accordance with the characteristics of the person to whom it is applied. As she explains, "the goal of these techniques I'm developing is to determine if there are groups of individuals for whom the diagnostic test has an optimal behaviour, or, what is more important, whether groups of individuals exist for whom the test is not useful."

Before devoting herself to statistical research, Rodríguez-Álvarez worked as a computer scientist for a private company. After completing her degree in Mathematics in 1999, she obtained a grant to work in an IT consulting firm in Galicia, where she worked for eight months training as a programmer and a developer of computer-based applications. She subsequently spent four years in the private sector, where she held a variety of positions. "There came a time when I began to miss the more mathematical and statistical side of the jobs I was doing," she says, "and was looking for an opportunity to apply what I had learned." It was then that she decided to continue her training by doing a PhD in statistics, and after that a master in biostatistics, and "I got the research bug and decided do my thesis." On completion of her thesis, she obtained a contract from the Xunta de Galicia (Autonomous Government of Galicia) as a postdoctoral researcher at the University of Vigo (UVIGO), where she worked from 2013 to 2016, after which she moved to the BCAM, where she is currently employed.

As a woman researcher, she is fully aware of the scarcity of women in STEM (Science, Technology, Engineering and Mathematics) disciplines. "One of the main problems is that these fields are regarded as being very masculine, and it's easy to feel that as a woman you are out of place there," she says. And while she goes on to say that she has never felt any overt discrimination, after speaking with other female colleagues she realizes that an underlying gender bias exists that is subtle enough to remain unconscious, because it is deeply interiorized and appears natural. Above all, she thinks that this is due to the fact that "we are taught very early on that these disciplines are not for us." In order to change this situation, she firmly believes that there has to be a critical mass of women engaged in the scientific workplace and in jobs with responsibility. Furthermore, she concludes: "It would benefit everybody, not only women. We bring diversity, different perspectives, life experience, views on reality and alternative ways of doing things, something applicable to all groups and collectives that are currently under-represented."

Rodríguez-Álvarez was scheduled to be one of the speakers at the first Diálogo #steMatEsElla, a series of discussions between students and professional mathematicians organized by the RSME and the EJE&CON association, with the collaboration of the ICMAT and the BCAM, until technical problems prevented her from taking part in the event.

Image: María Xosé Rodríguez-Álvarez

María Xosé Rodríguez-Álvarez giving a talk.

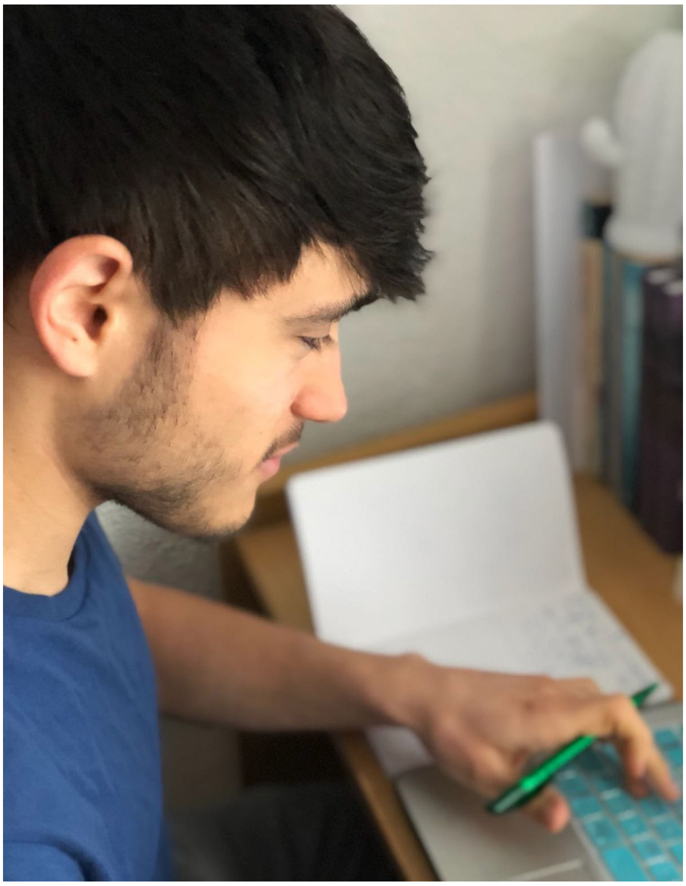
ICMAT
INSTITUTO DE CIENCIAS MATEMÁTICAS

PROFILE: Álvaro Romaniega (ICMAT)

"I joined the ICMAT by chance"

While at the ICMAT, Álvaro Romaniega (Aranda de Duero, 1994) showed a great interest in subjects such as Mathematics, Physics and Chemistry, proof of which is that in 2012 he was awarded the silver medal for the latter two subjects in the national scientific olympiads. This passion led him to studying Physics at the University of Valladolid and later to a master in Theoretical Physics at the Complutense University of Madrid. It was then that he realized that what he wanted was to make mathematics his working toolkit. So after meeting ICMAT researcher Alberto Enciso in 2017, he decided to apply to the Institute to do his PhD thesis on the analysis of partial differential equations, nodal sets, fluid dynamics and random fields.

Image: Álvaro Romaniega



Álvaro Romaniega working in his room at Residencia de Estudiantes (Madrid). He has obtained a grant for staying the course 2020-2021.

Hugo Barcia

Álvaro Romaniega is at present starting out on what will in all probability be his last year at the ICMAT. This is now his main objective after three years spent working on his doctoral thesis under the supervision of ICMAT researchers Alberto Enciso and Daniel Peralta-Salas, together with whom he is conducting research work in a field situated between the analysis of partial differential equations, probability theory and random fields, in the context of fluid mechanics, areas in which his supervisors are experts. Says Romaniega: "For random functions, we're extending types of results that they already had obtained for deterministic fields." Specifically, his task has been to extend the results obtained by his two supervisors, not only for deterministic fields but also for random functions. They have thereby arrived at a solution to a conjecture about fluid flows made by Soviet and Russian mathematician Vladimir Arnold in the 20th century.

As Romaniega himself admits, he joined the ICMAT "by chance." After completing his degree in Physics and a master in Theoretical Physics, he intended to continue along the same pathway, until a fellow student introduced him to Enciso. After a conversation with him, Romaniega was persuaded to do a PhD under Enciso's joint supervision with Peralta-Salas. This eventual switch to mathematics was not a result of chance as such, because ever since completing his degree the researcher had gradually specialized in theoretical physics, which is more closely concerned with the mathematical side of physics.

Reflecting on his time at the ICMAT, he especially mentions the good working atmosphere, because "there are some fine people you can talk with and have really interesting conversations." Due to the pandemic, however, this human contact has been reduced to a minimum. "It hasn't stopped us working," he adds, "but you can notice the difference." Even so, he has been able to keep up the pace and works on his thesis with his supervisors via video calls. What he has been unable to do is the long-term stay he had planned abroad at King's College in London. His original intention had been to spend the month of May last year in Tel Aviv, and he also wanted to go to Princeton, but the pandemic put paid to all those plans. "I still hope to go ahead with that in the spring," he says.

Those plans also included starting to teach in 2020, but COVID-19 prevented him from doing that too. Faced with this unexpected situation, Romaniega has had to put thoughts about his immediate future on hold, and is not yet sure what subject he is going to address for his post-doctorate. "I still have time before deciding on that," he says. However, one thing he is certain about is that it will not be too far removed from what he is currently working on in his thesis – "in order not to have to start from scratch."

And, what does Romaniega do in his spare time? In answer to this question, this young researcher says that one of his favourite pastime is practising sport, "because it's good for both the body and the mind." He also likes reading about subjects other than mathematics, but admits that he devotes a lot of his free time to "a blog where I discuss issues concerning economics and political philosophy".

INTERVIEW: Nuria Oliver (ELLIS, Data-Pop Alliance, Vodafone Institute and Presidencia de la Generalitat Valenciana)

"It is satisfactory for me to know that we are contributing to a greater understanding of the world and the ways to improve it"

Nuria Oliver is currently one of the foremost specialists in artificial intelligence and data science in Spain. A graduate in Telecommunications Engineering at the Universidad Politécnica de Madrid and who completed her PhD at the Massachusetts Institute of Technology (MIT) MediaLab, she has focused her career over recent years in the application of big data for the social good. She is the vice-chair and co-founder of ELLIS (European Laboratory for Learning and Intelligence Systems), a European non-profit association created by the European scientific research community in machine learning, as well as being the chief data scientist with the Data-Pop Alliance, an NGO devoted to the use of data and artificial intelligence for the common good. She is also the chief scientific advisor for the Vodafone Institute, a think tank located in Berlin and dedicated to studying the intersection between technology and society. In addition, she is also an independent advisor for Bankia. Since March, she has been a commissioner for Artificial Intelligence and COVID-19 at the Presidencia de la Generalitat Valenciana.

On October 7th of 2020, Oliver inaugurated the series of talks entitled *Diálogos #steMatEsElla* with her own talk "Data, data, data". These conferences constitute one of the main events in the third edition of the eponymous mentoring and advancement of STEM talent programme aimed at undergraduate and master students. It is organized by the Real Sociedad Matemática Española (RSME) and the Asociación Española de Ejecutiv@s y Consejer@s (EJE&CON), in collaboration with the ICMAT and the Basque Center for Applied Mathematics (BCAM).

Laura Moreno Iraola

How and why did you choose to work in the field of data science?

Actually, my discipline is Artificial Intelligence. While I was studying Telecommunications Engineering (at the Universidad Politécnica de Madrid), I did a project on neural networks with a woman professor at the Department of Mathematics. In a way, that was my discovery of Artificial Intelligence (AI). I was fascinated with being able to make systems and algorithms learn or do intelligent things, because it seemed like something magical. I subsequently did my final-year project on computer vision, an area that's part of AI, and decided to go to the USA to do my PhD in the field of perceptual intelligence. Since then, I've pursued a career with important contributions to the modelling of human behaviour, both individually and as part of a group, using artificial intelligence techniques and the development of interactive intelligence systems based on these models on human behaviour and feelings, etc.

I lived in the United States until 2007, when I returned to Spain to work for Telefónica as scientific director of R+D. My main task there was to help set up a research department, and also to put together an international interdisciplinary research team in areas that at that time were not at all common in a telecommunications company: fields like the modelling of human behaviour, unstructured data analysis using artificial intelligence techniques, and so on. It was thanks to this work that I began to develop aggregated human behaviour projects on a large scale, on the basis of aggregated and anonymized data on the mobile telephone network.

> "I was fascinated with being able to make systems and algorithms learn or do intelligent things, because it seemed like something magical"

Why has big data become so important over recent years?

The explosion of data is the result of different trends and circumstances, the first of which is the ubiquity of cell phones. There are now more of these mobile and smartphones in the world than human beings. All of our interactions through these devices leave a digital footprint and generate an enormous amount of data. Furthermore, we're also digitizing the physical world by means of sensors, such as those that can be found in cars and cities. There are also a lot of data recorded in a scientific context; those obtained by particle accelerators, astronomical data, DNA sequencing data or the results from radiology tests. In the end, these interactions generate massive amounts of data, as well as what is known as the data economy, which this year alone in Europe is estimated to amount to more than seven hundred billion euros.

What are the mathematics involved in big data?

Different techniques are employed, depending on whether we classify the data into different groups or if we want to predict phenomena, time series, or do clustering (grouping into different categories) using different tools from this discipline, which is known as machine learning, automatic or statistical learning.

What do you think are the greatest challenges right now?

There are technical challenges: data collection, storage, maintenance, access security, to ensure security is upheld... There are also challenges concerning data analysis, because the techniques are not perfect, and in many cases we don't

Image: Kristof Roomp

Since March, Nuria Oliver has been a commissioner for Artificial Intelligence and COVID-19 at the Presidencia de la Generalitat Valenciana.

have labels for the different categories. Challenges also exist regarding model generalization, because in the end the data provide only a partial vision of reality. Likewise, there's the question of algorithmic bias, that is, whether or not they are giving rise to discrimination. Lastly, a very current challenge is data capture in real time; many scenarios exist in which this can be of great value, including for example public health or pandemic scenarios, although in 99% of cases these are post hoc analyses.

What about the ethics?

From this point of view, I always like to speak about it in a general context that seeks to group together the great majority of proposals made in the literature to date, including that from the European Commission, many of the artificial intelligence national strategies or from organizations such as the ionCube of the ACM. In this context, I call it FATEN, because there are five main dimensions: **F**, for *"fairness"*, that is, to ensure that the algorithms do not discriminate; **A**, which is three-fold: *"accountability"*, to distinguish clearly the attribution of responsibility regarding the consequences of the use of the data and the use of the algorithms that analyze these data; *"autonomy"*, to always ensure the protection of human autonomy, which is a fundamental principle of ethics in the West, although all those interactions with the intelligent systems in our cell phones that try to modify or influence our own behaviour and decision-making in a subliminal way, and are thereby violating this principle of autonomy. **A** also refers to *"augmentation"*, increasing human intelligence rather than replacing it. In other words, to achieve a model in which to ensure that our human skills are complemented by systems of artificial intelligence. **T** refers to *"trust"* and transparency; that is, if we ensure that the algorithms are interpretable we can explain what they are telling us and why, as well as why they are recommending or classifying something the way they do. **E** comes from *"education"*; in my opinion, it's a priority to make an ambitious investment in this respect, and in many areas, from compulsory education to the personal education of workers, whose professions are being affected by this revolution. To say nothing of the education of society at large, and of the political class and its leaders, to enable them all to make informed decisions. By cheating a bit, **E** also covers "beneficence", which refers to the principle of maximizing the positive impact of the data and ensuring their veracity, diversity and sustainability. Finally, **N** refers to the principle of "non-maleficence", the aim of which is to minimize the negative impact and ensure security, reliability and reproducibility, always guaranteeing the personal privacy of people.

"A very current challenge is data capture in real time"

These ideas are reflected in the different projects you're involved in, using artificial intelligence techniques for the common good. Can you tell us a little about that?

At ELLIS, a non-profit European association of which I am the vice-chair and co-founder, we try to attract, retain and cultivate the coming European generations of excellent research in machine learning. We've already launched various initiatives, one of which is the creation of units in ELLISs consisting of teams of research excellence in machine learning and associated areas. With the support of the Generalitat Valenciana (Autonomous Government of Valencia), I presented a proposal for the creation of one of these units in Alicante that is called the Institute of Artificial Intelligence for Humanity, which has recently been approved. One of the fields of research is the modelling of human behaviour, both individually in as part of a group, using techniques of artificial intelligence. In the latter case, the purpose is to analyze the obtention of the 17 objectives of sustainable development. Data science is used to measures whether or not they are being attained and how to speed up their fulfilment.

I'm also working on social issues as part of my role as chief data scientist with Data-Pop Alliance, an NGO devoted to the use of data and artificial intelligence for the social good. For example, we've recently written an article on technology, data and COVID-19, published by the Vodafone Institute for Society and Communications, a think tank located in Berlin and of which I am the chief scientific advisor, and where we study the intersection between technology and society. Lastly, my latest post is that a commissioner for Artificial Intelligence and COVID-19 for the Presidencia de la Generalitat Valenciana.

What's your work in this position?

I lead a team consisting of about twenty male and female researchers belonging to the system in Valencia, who work voluntarily. This team is divided into four areas amalgamated together in data analysis using statistical, advanced analysis and machine learning techniques; the analysis of human mobility on a large scale and based on aggregated data from the mobile telephone network; computerized epidemiological models, two of which, one on individuals and the other on metapopulations, we have developed ourselves in order to predict the evolution of the pandemic and to conduct simulations in different scenarios; predictive models for use in ICUs, for example, hospitalizations, prevalence, etc., and citizen science. We've set up a large public survey on COVID-19 that has become the biggest in Spain and one of the largest in the world. This provides us with information about the actual situation and about public perception of the pandemic, in the light of the lack of data and their quality. We've devoted most of our time to this, because it requires ongoing analysis, data updating and monitoring.

You were involved in a project to eradicate malaria in Africa by means of data science when the pandemic broke out. Could you tell us a little about this project?

It began when I was the director of worldwide research into data science for Vodafone, and I set up a collaboration with Southampton University and the Bill and Melinda Gates Foundation, both of which were very active in the issue of malaria in Africa, particularly in Mozambique, the country where we carried out the study. It was here where for the first time we used aggregated and anonymized data from the mobile telephone network to model human mobility, which plays an important role in the geographical propagation of infectious diseases, whether they are transmitted between human beings, like the coronavirus, or whether they use a vector, such as a mosquito, which happens in the case of malaria. We analyzed the sources and the destinations, and the zones that import and export malaria, and we identified the corridors with greatest mobility that may give rise to this phenomenon of importation and exportation in the country, and we've issued a number of recommendations for the policies adopted in the struggle to eradicate malaria. Further additional work will have to be done in the coming months in this regard, because the team has currently been busy on the modelization of mobility during the coronavirus pandemic.

"We've set up a large public survey on COVID-19 that has become the biggest in Spain and one of the largest in the world"

What benefits do you derive from your participation in projects of this type?

The satisfaction from knowing that our work is having a positive impact on society, and from showing that with scientific knowledge and our own knowledge and experience we are contributing to a greater understanding of the world and the ways to improve it.

In regard to the situation of women in STEM, what has it been like for you in a field such as data science that is so dominated by men? Have you come across any discrimination?

I've never come across any explicit discrimination, but I've been in a minority throughout most of my professional life, because furthermore fewer and fewer girls choose to study Computer Science or related Engineering subjects. During all my career, I've found myself in situations in which I've been the only woman. Any collective that's in a minority, which is the case of women, is a priori in a situation of vulnerability, because human beings tend towards what is known as homophily, that is, we feel more comfortable, closer to each other and have preference for people who are like us, so unconsciously minorities remain excluded. It's something we have to become aware of and try to remedy it by adopting active and explicit measures that encourage diversity in groups whatever they may be.

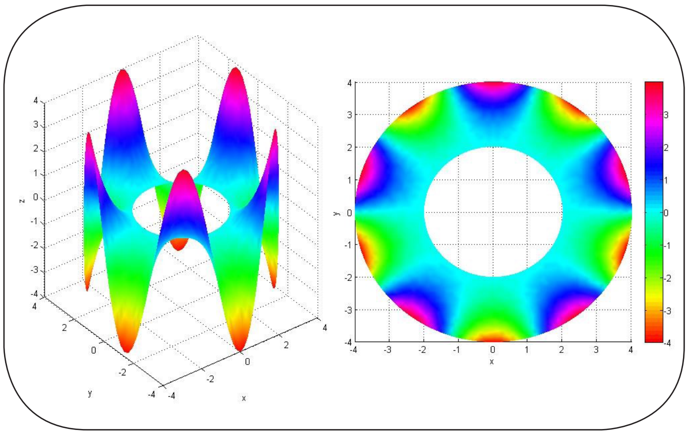
Why do you think there are still so few women involved in STEM disciplines?

There any various different reasons, which I'll try to summarize by mentioning just four. In the first place, because of a large degree of stereotyping where professional profiles in this field are concerned, especially in what these courses consist of, and even in the way they are taught. Secondly, the gender bias that affects both men and women and which makes us underestimate women who are supposed to be on equal terms with their male peers. There are adolescents who feel they are not good enough to do those courses despite having an excellent academic record, because technical courses have the reputation of being difficult. Thirdly, there's a lack of recognition and visibility of women in general. As regards science and technology, as well as the low presence of women, those engaged in these fields lack visibility, almost as if we didn't exist. This is patently obvious in everything from the pay gap to the ridiculously small number of women who have won a Nobel Prize or other kinds of awards. Lastly, the fourth reason is one that is specific to the technological sector. There's an extremely misogynist and sexist culture rooted in many areas, both in companies large and small as well as in network programming, which is known as "brogrammer culture", a phrase coined from the words "brother" and "programmer". The first term is understood as referring to a member of the North American fraternity with a highly sexist culture. Translated to the context of programming and informatics, this culture is largely what makes 58% of the women who have overcome all the earlier barriers and work in the technological sector, decide to leave it after just 10 years, not because they can't balance private and professional life, because the sector is in fact good in that sense, but precisely because of the existing culture.

SCIENTIFIC REVIEW: The Dirichlet Problem for the Laplace Equation

Title: "Harmonic measure and quantitative connectivity: geometric characterization of the Lp-solvability of the Dirichlet problem"
Authors: Jonas Azzam, Steve Hofmann, José María Martell, Mihalis Mourgoglou and Xavier Tolsa
Source: *Inventiones Mathematicae*, 222, 881-993 (2020)

Source: Fourthirtytwo



Temperature distribution in the $2 < |x| < 4$ corona with data at the boundary $u = 0$ si $|x| = 2$ and $u = 4$ sen (5θ) si $|x| = 2$.

The Laplace operator, or Laplacian, is a second order elliptic differential operator named after the physicist and mathematician Pierre-Simon Laplace. In $\mathbb{R}^n$ it is expressed as

$$\Delta u = \frac{\partial^2 u}{\partial x_1^2} + \frac{\partial^2 u}{\partial x_2^2} + \cdots + \frac{\partial^2 u}{\partial x_n^2}, \qquad u = u(x_1, x_2, \ldots, x_n).$$

In other words, it is the sum of the elements of the diagonal of the hessian matrix that contains all the second derivates of the function u. The solutions to the Laplace equation, that is, the functions u that satisfy $\Delta u = 0$ in a certain open set Ω, are known as harmonic functions. This equation appears in the study of certain problems in hydrodynamics, electrostatics, gravitational potentials and heat diffusion.

The Dirichlet problem

$$\begin{cases} \Delta u = 0 \ \text{ in } \Omega \\ u = f \ \text{ in } \partial\Omega, \end{cases}$$

consists in finding a harmonic function u in an open set Ω, so that its value in $\partial\Omega$, the so-called boundary of Ω, is predetermined and is given by the function f. For instance, this problem enables us to determine how heat is diffused in an object with predetermined temperature at is boundary. This boundary temperature does not change over time, but we allow it to stabilize in the rest of the body. The temperature distribution inside the object is precisely the solution to the corresponding Dirichlet problem.

When solving the Dirichlet problem, it is important to preserve some of the properties, both qualitative and quantitative, that are satisfied at the boundary. For example, if the function f is continuous at the boundary, is it possible to find a solution that is also continuous as we approach this boundary? We know that by using the so-called harmonic measure we can find a solution that satisfies the well-known maximum principle. In the case of heat diffusion, this principle ensures that the highest temperature inside an object is at most the highest temperature at the boundary, and analogously the same occurs where the minimum temperature is concerned.

However, this property provides global information about the solution rather than about its local behaviour. If, for example, a corona (like that in the image) in which the temperature remains mainly at 0ºC at the boundary, and only in a small region of this boundary, the temperature reaches 300ºC, the maximum principle would naturally indicates that the temperature in the interior would be between 0ºC and 300ºC. Furthermore, in the same way that the temperature in a room with a lighted fire is very high close to the fire, we may imagine that it is around this zone where the temperature reaches 300ºC that the temperature will be high, and further away it will be lower. Nevertheless, in the world of mathematics this idea corresponds precisely to the fact that the solution behaves continuously in a neighborhood of the boundary, and will depend on the geometric and topological properties of the domain Ω of the equation. In order to determine when the solutions associated with continuous data behave continuously when approaching the boundary, the well-known Wiener criterion is employed, and it requires a certain "thickness" of the region that remains outside the domain.

In general, the geometric and topological properties of the domain play an important role in the study of the Dirichlet problem. In 1977, Björn Dahlberg proved that in a domain with Lipschitz-type boundary – such as that of a metallic saw for cutting wood – the Dirichlet problem could be solved if the function representing the values at the boundary is square-integrable with respect to the surface measure at the boundary. The solutions constructed using the harmonic measure will then behave appropriately in a non-tangential manner; that is, in the cones whose vertices are at the boundary. This, for example, enables the functions that suddenly acquire very large values in certain regions at the boundary to be taken into account, such as that mentioned above.

This result was generalized in 1990 by Guy David and David Jerison, and independently in 1989 by Stephen Semmes. These authors proved that in the so-called non-tangential domains – introduced by David Jerison and Carlos Kenig – the Dirichlet problem could be solved for those functions at the boundary that are integrable when elevated to a sufficiently high power.

Thus, it was also possible to solve the problem with functions at the boundary that had singularities, although at that time it appeared necessary for the boundaries to possess a certain regularity. In both the Lipschitz case and in the non-tangential domains, the boundaries are uniformally rectifiable, which means that in each piece of the boundary there exists a fixed proportion – which may be very small – that is essentially like a saw blade.

Over the last decade, different researchers have attempted to determine the most general context in which the Dirichlet problem can be solved, with functions at the boundary that may be singular. The work conducted by José María Martell, Steve Hofmann and Ignacio Uriarte-Tuero, and by Jonas Azzam, Steve Hofmann, José María Martell, Kaj Nyström and Tatiana Toro, established that this context was that of the non-tangential domains, with the hypothesis that the points within each domain could be reasonably connected.

In the general case, that is, without knowing whether the domain has connectivity properties, Steve Hofmann, Phi Le, José María Martell and Kaj Nyström demonstrated that if the Dirichlet problem can be solved, then necessarily the boundary is uniformally rectifiable. However, it was known that this regularity was not a sufficient condition for guaranteeing the solution to the problem, so it was necessary to impose some additional property of weak connectivity. This property was finally discovered by Jonas Azzam, Steve Hofmann, José María Martell, Mihalis Mourgolou and Xavier Tolsa. In their work, consisting of 113 pages and published in the journal Inventiones Mathematicae, brought to a close the question previously posed: by providing a geometric characterization of the domains in which the Dirichlet problem with data that when raised to a sufficiently high power are integrable, and whose solutions possess a good non-tangential behaviour.

This characterization includes two conditions; one regarding the regularity of the boundary and the other concerning the connectivity of the domain. More specifically, the boundary of the domain must be uniformally rectifiable, and must also ensure a non-tangential accessibility to a portion of the boundary (along a "carrot-shaped" path). The result identifies the class of domains precisely; that is, it shows that not only can the problem be solved in this class, but also that if it can indeed be solved, then the domain must necessarily satisfy the two aforementioned conditions.

SCIENTIFIC REVIEW: SO(p, q)-Higgs bundles and higher Teichmüller components

Original title: "SO(p, q)-Higgs bundles and higher Teichmüller components"
Authors: Marta Aparicio-Arroyo, Steven Bradlow, Brian Collier, Oscar García-Prada, Peter B. Gothen, André Oliveira
Source: *Inventiones Mathematicae,* 218 (2019) 197–299

Summary

Given a connected closed oriented smooth surface S of genus $g \geq 2$, the Teichmüller space of S parametrizes complex structures on S, up to diffeomorphisms of S isotopic to the identity. A complex structure is simply a way of identifying locally the surface S with open sets of the complex numbers. A surface equipped with a complex structure is called a Riemann surface. Riemann's moduli space of complex projective algebraic curves of genus g is obtained as the quotient of Teichmüller space by the mapping class group of S. The Teichmüller space of S can be identified with a topological component of the space of equivalence classes of representations of the fundamental group of S in PSL$(2, \mathbb{R})$. This space is often referred as the character variety of the fundamental group of S in PSL$(2, \mathbb{R})$. This component is defined by considering the holonomy representation of the hyperbolic metric associated to a complex structure via Riemann's uniformization theorem, and consists entirely of discrete and faithful representations. These are known as Fuchsian representations. The Teichmüller space plays a very important role in many areas of mathematics, including complex analysis, lower dimensional topology, algebraic geometry, hyperbolic geometry, geometric group theory, dynamical systems, etc.

In 1987 Nigel Hitchin introduced the theory of Higgs bundles over Riemann surfaces. This theory has had an enormous impact in many areas of mathematics and theoretical physics. A main outcome of this theory is the non-abelian Hodge correspondence establishing, for any semisimple Lie group G, a homeomorphism of the G-character variety of the fundamental group of the surface S as above, with the moduli space of G-Higgs bundles over S equipped with a complex structure. Using this correspondence, in 1992 Hitchin identified a special component of the character variety of the fundamental group of S in PSL$(n, \mathbb{R})$ —and more generally in a split real form of any complex semisimple Lie group. This component, known as Hitchin component, shares many properties with the Teichmüller space of S. In fact it contains the usual Teichmüller space via the irreducible Kostant principal representation of PSL$(2, \mathbb{R})$ in PSL$(n, \mathbb{R})$. Moreover, as Teichmüller space, the Hitchin component consists entirely of discrete and faithful representations of the fundamental group. This was proved by François Labourie in 2006, after introducing the important concept of Anosov representation.

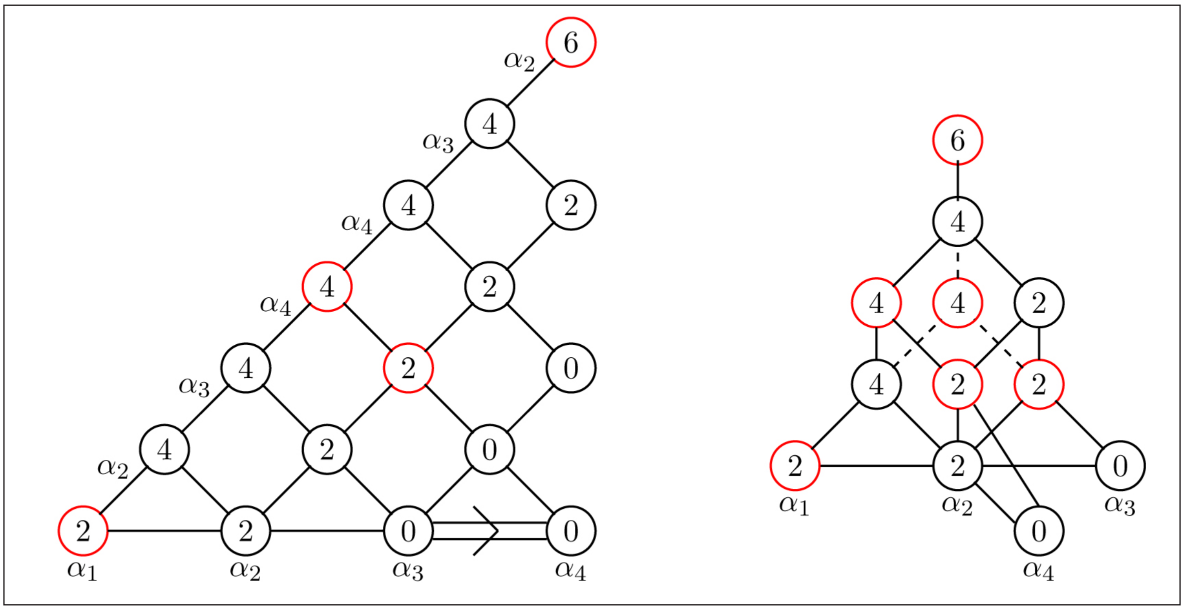
Starting around 2000, character varieties of the fundamental group for non-compact Hermitian groups were under investigation. A Hermitian group is the isometry group of a symmetric space which is Kähler. The group PSL$(2, \mathbb{R})$ is both split and Hermitian, being the isometry group of the hyperbolic plane. Again, using the non-abelian Hodge correspondence and the theory of Higgs bundles, new components, consisting entirely of discrete and faithful representations, were found in various works by Olivier Biquard, Steve Bradlow, Oscar García-Prada, Peter Gothen, Ignasi Mundet and Roberto Rubio. Bounded cohomology methods were used by Marc Burger, Alessandra Iozzi, and Anna Wienhard to study various properties of the representations in these components. These components, together with the Hitchin components were referred as higher Teichmüller components. As Teichmüller space, they all have the property that the mapping class group of S acts freely.

For a long time, it was believed that split and Hermitian groups where the only classes of groups for which higher Teichmüller components existed. The paper under review proves the existence of such type of components also for the family of groups SO(p, q), even when they are neither split nor Hermitian. Although this was not originally expected, it was not entirely surprising. Few years earlier, Marta Aparicio in her 2009 PhD thesis studied SO(p, q)-Higgs bundles using the Morse theoretic methods introduced by Hitchin to count components. The original expectation was that components were parametrized by the obvious topological invariants, but it turned out that there were more minima of the Hitchin Morse function than expected, leaving the possibility for the existence of components that are not accounted by the usual topological invariants —a common characteristic of higher Teichmüller spaces. Another evidence came from the recent work by Olivier Guichard and Anna Wienhard (2016), where they introduce a notion of positive structure on certain real Lie groups, leading to a notion of positivity for a representation of the fundamental group. They classify the groups admitting positive structures, finding that in addition to split and Hermitian groups, the family SO(p, q) is also there. Guichard-Labourie-Wienhard conjecture that only the groups with positive structure admit higher Teichmüller components which consist entirely of positive representations. The work under review strongly supports this conjecture. In the paper there is also a complete counting of the topological components of the SO(p, q)-character variety.

The paper has also paved the way for a general Higgs bundle approach to the characterization of higher Teichmüller components. From the Higgs bundle point of view, the higher Teichmüller components for Hermitian groups and for SO(p, q) are constructed using what is called a Cayley correspondence. This identifies a bunch of components of the moduli space of G-Higgs bundles with a moduli space of objects similar to Higgs bundles for another Lie group, the Cayley partner group. It turns out that the Hitchin component for split real groups admits also an interpretation of this sort. Here, the Cayley partner moduli space is the base of the famous Hitchin integrable system. The natural conjecture that emerged from the paper is that higher Teichmüller components must arise from a Cayley correspondence. In a recent paper (arXiv:2101.09377), Steven Bradlow, Brian Collier, Oscar García- Prada, Peter B. Gothen and André Oliveira, have constructed a Cayley correspondence for all the groups that admit a positive structure in the sense of Guichard-Wienhard. This correspondence is based on a classification of the real groups that admit a particular way, called magical, of having PSL(2, $\mathbb{R}$) embedded. The Kostant principal embedding in the split real forms is a particular case of a magical embedding. The list of groups admitting magical embeddings coincides with that of the groups admitting positive structures, including, in addition to split groups, Hermitian groups and SO(p, q), the quaternionic real forms of the groups F_4, E_6, E_7 and E_8.

For a survey on this subject, the reader my consult the paper by Oscar García-Prada, "Higgs bundles and higher Teichmüller spaces, in: A. Papadopoulos (Ed.), *Handbook on Teichmüller Theory*, vol. VII, European Mathematical Society, 2020.

Image: Brian Collier



Partially ordered sets of roots for magical nilpotent elements of the Lie algebras of SO(3, 6) and SO(3, 5) related to higher Teichmüller components.

MATHEMATICS TODAY: ICMAT News

Institutional

María Blasco assumes the presidency of the SOMM Alliance of the Centres and Units of Excellence

Image: María Blasco

María Blasco

María Blasco, director of the National Centre for Cancer Research (CNIO), is the new chairperson of the Severo Ochoa – María de Maeztu Alliance, SOMMa. Until now, she had been the first vice-president of this Alliance. She replaces Luis Serrano, director of the Centre for Genomic Regulation (CRG), and is accompanied in her new post by members of the vice-presidency Mª José Sanz, director of the Basque Centre for Climate Change (BC3), and Antonio Molina, director of the Universidad Politécnica de Madrid joint research Centre for Plant Biotechnology and Genomics and the National Research Institute for Agriculture and Food Technology (CBGP-UPM-INIA), who is leaving the secretariat and is replaced by Isabel Márquez from the Astrophysics Institute of Andalucía (IAA-CSIC).

SOMMa brings together more than 50 leading Spanish research centres, including the ICMAT, and consists of more than 8,500 researchers of both sexes. It was officially launched on October 18th, 2017, as an initiative for raising the visibility of Spanish science as recognized by the R+D+I National Plan Severo Ochoa and María de Maeztu seals of excellence.

The principle innovative scientific associations and companies call for R+D+i to be placed at the heart of national strategy

The Severo Ochoa Centres and María de Maeztu Units Alliance (SOMMa), to which belong the ICMAT, the Spanish Association for Cancer Research (ASEICA) and the Spanish Association of Biocompanies (AseBio), centres consisting of almost ten thousand researchers in the public and private sectors, hundreds of research centres and almost 300 leading companies in the field of biotechnology. They have joined forces to urge politicians and policy-makers to transform the country. In a recently published document they ask among other measures for an increase in the 2.5% state investment devoted to R+D+i by 2027 in order to bring about a structural change in the current economic model.

Image: SOMMa

Results, awards and distinctions

How can the lines of a magnetic field be knotted together?

Image: Benjamin Bode

Benjamin Bode has obtained a Marie Sklodowska-Curie contract to study the mathematical knots that appear in different contexts of physics.

ICMAT postdoctoral research Benjamin Bode has received a Marie Skłodowska-Curie contract from the Institute to study the mathematical knots that appear in different contexts of physics, such as the lines of a magnetic field. Under the supervision of Daniel Peralta-Salas (ICMAT-CSIC), together they will look for a description of the type of knots and the movement of knots that are possible in these dynamic systems that arise in physics. A mathematical knot may be compared to a looped piece of string with its two ends glued together. While it is possible to construct an infinite number of different knots, it is still not known if this actually happens in the world of physics.

Artificial intelligence for improving the treatment of industrial waste

In collaboration with Ferrovial, Florentino Borondo, a professor with the Chemistry Department at the Autonomous University of Madrid (UAM) and a member of the ICMAT, is at the head of a new project for creating a system of sensorization and monitoring indicators in the treatment facilities of urban and industrial waste. The purpose is to "minimize the cost" of productivity in these plants and "maximize the replicability" in other facilities. In addition, a predictive maintenance system using artificial intelligence will also be developed as part of the project.

This undertaking forms part of the 2nd Programme to promote the transfer of knowledge sponsored by the Autonomous University of Madrid (UAM) Vice-Rectorate for Innovation, Technology and Knowledge Transfer.

Image: ICMAT

Florentino Borondo is the head of a new project for creating a system of sensorization and monitoring indicators in the treatment facilities of urban and industrial waste.

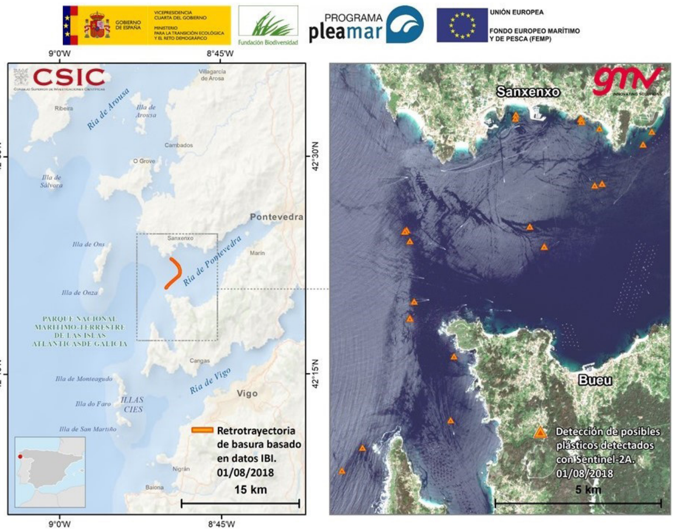
The BEWATS project, in which ICMAT researchers are involved, makes progress in the remote tracking system of beach waste on the coast of Galicia

Source: Universidad de Vigo, GMV

The University of Vigo and ICMAT researchers Ana María Mancho and Guillermo García Sánchez, together with the collaboration of the GMV company, the Biodiversity Foundation and the Demographic Challenge of the Ministry for Ecological Transition, have since December 2019 all been working on the BEWATS project, which is due to conclude in April of this year.

The aim of this project is to develop innovatory tools for tracking the origin and destination of waste in the estuaries and tidal inlets of Vigo and Pontevedra by means of satellite images and UAVs (Unmanned Aerial Vehicles). Specifically, the task undertaken by Mancho and García Sánchez is focused on the development of models for monitoring the routes followed by such waste. These models have helped to establish the limits and boundaries of the zones of origin of this waste throughout the different seasons of the year.

Image: ICMAT



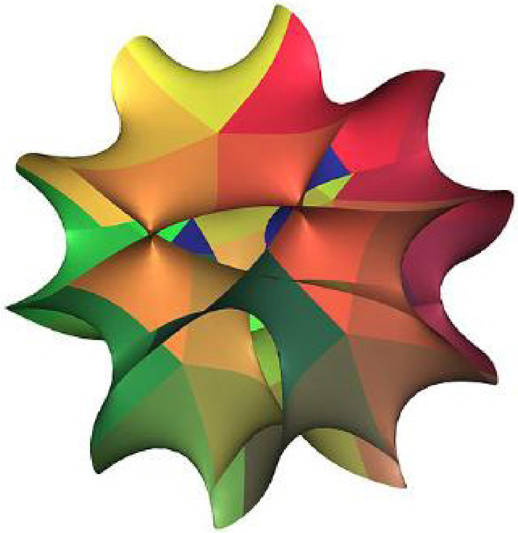
The task undertaken by Ana M. Mancho and Guillermo García Sánchez, ICMAT members, is focused on the development of models for monitoring the routes followed by such waste.

New mathematical solutions for the equations that explain space-time

Source: UCCUAM

Mario García-Fernández, a researcher at the Institute of Mathematical Sciences and the Autonomous University of Madrid, has presented his article "T-dual solutions of the Hull–Strominger system on non-Kähler threefolds" concerning new solutions to the Hull-Strominger system, the set of equations in non-algebraic Calabi-Yau-type spaces, which explain space-time in the Superstring Theory. In his paper, published in the *Journal für die reine und angewandte Mathematik* in 2020, the author also studies the qualitative properties of the new solutions found in regard to the (0,2)-type mirror symmetry conjectural proposal for non-algebraic complex spaces.

Image: Andrew J. Hanson



Bidimensional section of a six-dimensions Calabi-Yau manifold

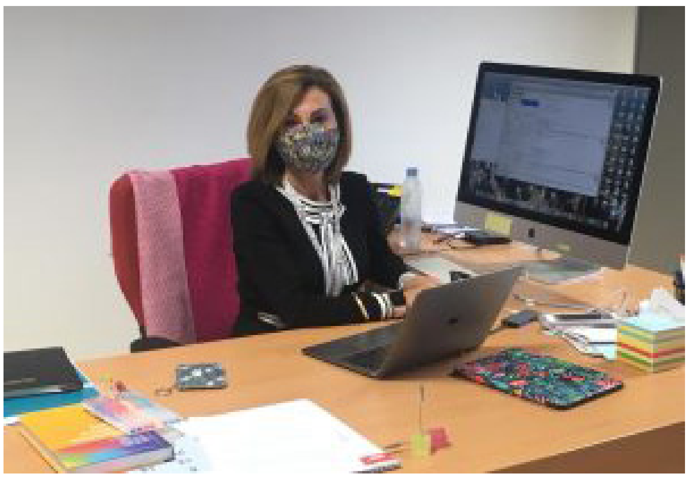
Altenea Biotech, the company headed by Núria Campillo, a visiting researcher at the ICMAT, is awarded the 2020 Madrid Impacta Prize

Artificial intelligence, machine learning and deep learning are playing an increasingly important role in the development of pharmaceutical products and chemical compounds. It is on these branches that the predictive models for physico-chemical, toxicological and pharmacological parameters employed for studying these compounds are based. It is thanks to these models that it is possible to speed up preclinical processes, make a better selection of the most promising compounds and maximize the chances of success, all of which means a reduction in both the design cost and development time of these products.

The biotechnology company Altenea Biotech, a spin-off of the Spanish National Scientific Research Council (CSIC) and the National Scientific and Technical Research Council of Argentina, is devoted to the design and implementation of these models and has received the 2020 Madrid Impacta award, conferred by Madrid City Hall in recognition of "the best business solutions to problems arising from COVID-19". The company is headed by Núria Campillo, a researcher with the Margarita Salas Centre for Biological Research (CSIC) and a visiting researcher at the ICMAT during the present 2020-2021 course.

The three companies distinguished with this award – Tucavi Car and Sycai Technologies, in addition to Altenea Biotech – will also receive an endowment of 8,000 euros each.

Image: ICMAT



Nuria Campillo is a researcher at the Margarita Salas Centre for Biological Research (CSIC) and a visiting researcher at the ICMAT.

Scientific activities

Harmonic analysis and PDEs meeting

In December of last year, the ICMAT, together with the London Mathematical Society Harmonic Analysis and PEDs Research Network, in which the Institute also participates, organized the online conference "Harmonic Analysis and PDEs Meeting", in which specialists in harmonic analysis hooked up to discuss applications in this field for the study of different problems. During the meeting talks were given by Gianmarco Brocchi (University of Birmingham), Vjekoslav Kovač (University of Zagreb) and Ioannis Parissis (UPV/EHU & Ikerbasque).

Image: ICMAT

Harmonic analysis and PDEs meeting celebrated in 2010

Pentagonal Transformation and integrable partial differential equations at the latest ICMAT-UCM Colloquium

"Integrable PDEs and Pentagram Maps" was the title of the latest ICMAT-UCM Colloquy, held last year on December 16th and conducted online. It was imparted by professor of Mathematics at the University of Toronto (Canada), Boris Khesin, who presented certain generalizations of a curious phenomenon observed by the mathematician Richard Schwartz in 1992, and which appeared when making constructions starting from polygons of random dimensions. This subject is associated with different areas of mathematics, such as discrete and infinite-dimensional integrable systems, soliton equations, cluster algebras, Poisson invariant structures, friezes, etc.

Image: Toronto University

Boris Khesin gave the ICMAT-UCM Colloquium "Integrable PDEs and Pentagram Maps".

The Prisma Conference highlights the diversity in science, technology and innovation

As part of the run-up to the celebration of LGTB STEM Day last year on November 18th, the first edition of the PRISMA Conference was held in Spain on the 15th, 16th and 17th of that month. This was an event promoted by the homonymous association with the aim of raising awareness and visibility of people belonging to the LGTBIQA+ collective, not only in recognition of their work in the academic world, but also for their achievement in the performance of rigorous science. A further purpose was to create a sense of community and to generate safer and more inclusive spaces in which members of this collective might share their problems and experiences.

Image: PRISMA

PRISMA Conference poster

Mathematical culture and equality

El ICMAT receives the CSIC Seal of Accreditation for Gender Equality

The CSIC has awarded its Seal of Accreditation for Gender Equality to the ICMAT, after it gained the "highest score from the panel," as stated in the official announcement of the decision, in which it was also stated that "it met the requirements set out in the National Plan for Equality" and highlighted "the commitment of both the management and the personnel of the institute in matters of equality." Likewise, the Institute for Environmental Diagnosis and Water Studies (IDAEA) and the Institute of Marine Sciences (ICM) were also distinguished with an honourable mention.

The ICMAT created its Gender Commission (now known as the Equality Commission) in 2016, as part of the Severo Ochoa Center of Excellence programme, conceded by the Ministry for Science and Innovation. Since then, the ICMAT has undertaken activities aimed at different sectors of society with the aim of raising the visibility of women in the field of mathematics, and encouraging scientific vocation, especially among young girls.

This distinction is also endowed with 5,000 euros for the development of initiatives promoting gender equality.

Image: ICMAT

Ana Bravo (ICMAT-UAM) gave a workshop the 11th February, International Day of Women and Girls in Science in 2020.

The ICMAT becomes a new institutional member of European Women in Mathematics

The main objective of the association of European Women in Mathematics (EWM) is to increase the presence of woman in mathematics. For that purpose, different initiatives have been undertaken to encourage the pursuit of this discipline among women students, to support women in their careers, to contribute to setting up a network of specialists in the field and to make the presence of woman more visible in mathematics. In early 2012, the ICMAT became an institutional member of the EWM, and through the activities of its Equality Commission collaborates in the achievement of this objective.

Founded in 1986, EWM has some one hundred members and 33 co-ordinators in different European countries. It organizes an annual general assembly and a summer school. Furthermore, it also publishes two newsletters every year as well as having its own website and a Facebook page. Thanks to the contributions made by its members, it sustains these initiatives, especially its travel grants, as well as round-table discussions and the running of communication platforms.

Image: EWM

The European Women in Mathematics association works for increasing the presence of woman in mathematics.

Silvia Bruno (*Red Eléctrica*) and María Jesús Carro (UCM) talk to STEM degree students

On Thursday February 25th, the second #SteMatEsElla: "¡Tú también puedes!" ("You can do it too!") dialogue was held, in which Silvia Bruno, the director of Innovación de Red Eléctrica, and María Jesús Carro, professor of Mathematical Analysis at the Complutense University of Madrid, shared their career-long experiences in the STEM field via video-link. Ana Bravo, a tenured lecturer at the UAM and a member of the ICMAT and the SteMatEsella Government Council, was responsible for managing and moderating the conversation. Some 50 people participated in the discussion, most of whom were STEM degree students who asked the questions and clarified their doubts with the speakers.

The aim of the #STEMatEsElla Dialogues programme is to bring leading exponents of STEM subjects into closer contact with students in the field in order to provide role models and to stimulate the exchange of thoughts and opinions in a relaxed and familiar environment. This forms part of the third edition of the SteMatEsElla programme promoted by the Asociación Española de Ejecutiv@s y Consejer@s (EJE&CON) and the Royal Spanish Mathematical Society (RSME), in collaboration with the ICMAT and the Basque Center for Applied Mathematics (BCAM), under the auspices of the Higher Institute for Internet Development (ISDI), the ICMAT Severo Ochoa project and the University of Oviedo Chair of Analytical Intelligence. This is an initiative whose purpose is to promote scientific and business careers among women degree students, university master students, PhD students in Mathematics and other related disciplines (grouped under the acronym CTIM).

Images: Red Eléctrica and María Jesús Carro

The second #SteMatEsElla dialogue, "¡Tú también puedes!", was a conversation between Silvia Bruno (Red Eléctrica) and María Jesús Carro (UCM).

The ICMAT joins in the commemoration of the International Day of Women and Girls in Science

As on previous occasions, on February 11th last year the ICMAT's Equality Commission held its annual commemoration of the International Day of Women and Girls in Science with a workshop and talk for 3rd, 4th and 5th year junior school pupils entitled "Mathematical Constellations", imparted by Marta Folgueira López, a full professor of Astronomy and Geodesics at the Complutense University of Madrid.

The event included the presentation of some of the geometric figures that can be found in the constellations as well as other astronomical curiosities. The concept of infinity was also introduced by means of pictures of the starry sky painted by women, and talk was given on some of the women who throughout history have contributed to the progress of astronomy and mathematics. The talk was followed by a workshop conducted with the Stellarium programme, in which the pupils were able to calculate the position of the Sun, the Moon, constellations and stars. In addition, they were able to simulate the sky according to time and positioning as well as creating astronomical effects, such as meteorite showers, lunar and solar eclipses, etc., and also constructing their own constellations.

Together with this activity, the ICMAT also launched a campaign on social networks in which researchers of both sexes spoke by video link about the women mathematicians who have influenced them most throughout their careers. Furthermore, a series of activities in collaboration with other centres on the Cantoblanco Campus belonging to the CSIC.

Image: Marta Folgueira López

Image of the talk "Constelaciones matemáticas"

History of the Mathematical Circle of Palermo, the largest mathematical society in the early 20th century, present at Mathematics at the Residencia

The context depicted in the novel *The Leopard* (Giuseppe Tomasi di Lampedusa, 1958) witnessed the flourishing of intense international mathematical activity. Giovanni Battsita Guccia, the nephew of the character from whom the title of the book is derived, was the founder of the Mathematical Circle of Palermo, which in 1914 became the largest mathematical society in the world.

Last year, On November 12th, Guillermo Curbera, a professor at the University of Seville, fathomed the origins and splendour of that scientific activity in his talk "Late 19th century in Palermo: Science between *The Leopard* and the Liberty style". The talk formed part of the series of events "Mathematics at the Residencia" organized by the ICMAT in collaboration with the Residencia de Estudiantes and the Vice-Presidency of Scientific Culture at the National Scientific Research Council (CSIC).

Image: Mathematical Circle of Palermo

Mathematical Circle of Palermo

Mathematics applied to robotics and contacts with extra-terrestrial life, at the ICMAT Science Week

Once again last year the ICMAT took part in the National Scientific Research Council (CSIC) Science and Technology Week, which was held throughout the month of November and included two talks aimed at a school-aged audience. The first of these talks, entitled "Hey! Where is Everybody?", was given by Alberto Ibort (ICMAT-UC3M) on November 4th. This researcher focused the activity on the apparent contradiction between the estimations of life in the universe and the lack of identification of such life. On the following day, David Martín de Diego (ICMAT-CSIC) spoke about the mathematics behind robotics.

Both talks were aimed at 4th-year secondary school students and conducted online. These meetings are available for viewing on the ICMAT YouTube channel.

Image: ICMAT

Alberto Ibort and David Martín de Diego gave, respectively, the following talks: "¡Eh! ¿Dónde está todo el mundo?" and "Matemáticas y robótica".

"Massive Numbers" at the 2020 European Researchers' Night

Activities throughout Europe were held on November 27th aimed at bringing science and those dedicated to science closer to the public at large. Together with other centres belonging to the Spanish National Scientific Research Council (CSIC) and Medialab Prado, the ICMAT participated in the joint initiative "Research with the CSIC at Medialab Prado".

Among other different workshops and experiments, ICMAT researcher Javier Aramayona conducted an online workshop devoted to massive numbers in which he outlined the challenges involved in managing these enormous figures that appear simply in everyday objects like decks of cards and whose use is vital for guaranteeing the security of our internet communications.

Image: ICMAT

Javier Aramayona in his talk "Números descomunales: Una pequeña ventana al infinito".

AGENDA

ICMAT Scientific activities

- **EECI International Graduate School on Control 2021**
  Date: 19-23 April 2021
  Place: ICMAT

- **Escuela JAE de Matemáticas 2021**
  Date: 21 June – 9 July 2021
  Place: ICMAT

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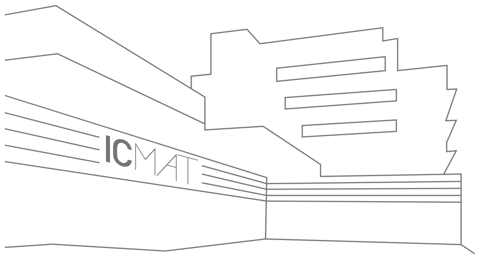

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