Strictly Mysterious

Dr. **Piotr Achinger** of the PAS Institute of Mathematics talks about the job of a mathematician and the importance of basic research – explaining why some projects are like snakes, but others are like octopuses.

Piotr Achinger, PhD
graduated in mathematics and computer science from the Faculty of Mathematics, Informatics, and Mechanics, University of Warsaw, in 2011. In 2015, he received his doctoral degree from the University of California, Berkeley, with the support of an International Fulbright Science & Technology Award. He spent a two-year postdoctoral research fellowship (European Post-Doctoral Institute) at the Banach Center in Warsaw and at Institut des Hautes Études Scientifiques (IHES) in Paris. In 2016, he took up a position as Assistant Professor at the Institute of Mathematics, Polish Academy of Sciences (PAS). He studies the topology of algebraic varieties and positive characteristic algebraic geometry. He has won a European Research Council (ERC) grant for a project on the topology of algebraic varieties and their applications in arithmetic, mathematical physics, and differential equations.

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ACADEMIA: **The subject of your project is "Homotopy Theory of Algebraic Varieties and Wild Ramification." Could you tell us something more about that?**
PIOTR ACHINGER: Of course, it's impossible to explain what I study both concisely and accurately, but that's a problem that applies not only to my research, and not only to mathematics. What I can do, however, is describe the field of study, namely algebraic geometry, a bit more clearly. It's a large branch of mathematics that's linked on the one hand to mathematical physics and differential geometry, or in a sense to describing reality, and on the other to number theory, which involves the study of problems that date back a very long time and pertain to prime numbers and divisibility. On the face of it, they don't seem to have much in common, but algebraic geometry makes it possible to link them in some very interesting ways, offering a uniform language to describe certain phenomena. That's why some ideas from mathematical physics can be used in number theory, and conversely. In mathematics, we've observed the intensification of this trend since the 1970s. Without algebraic geometry, however, there would be no communication, no common language, between these two ideas.

> Mathematics is an exact science that has exact proofs, but how do mathematicians know that a theorem is true before they start trying to prove it?

If we understand you correctly, you're working on deepening or elaborating a channel of communication between two domains – one of them is tangible, the other remains in the sphere of ideas and considerations.
Both are tangible. Questions present in number theory have recently found applications in such fields as cryptography, but that's not why we want to study them. Maybe I should explain in more detail what algebraic geometry is. It is interested in geometric objects described in an algebraic way. An example from math classes in high school: a circle in a plane with a center at (0, 0) and a radius $r = 1$ can be described with the equation $x^2 + y^2 = 1$

That's a very broad field, which was recently demonstrated during the awarding of the Fields Medal, the most prestigious prize in mathematics given to mathematicians under 40 years of age. Normally, two to four prizes are awarded every four years. This year, there have been four prizes, three of which are linked to my field of study.

Does this mean that this is now a popular subject among mathematicians?
Yes, indeed, it's the latest trend.

What was it about your work that appealed to strongly to the ERC?
I wrote my grant application very broadly, linking together different branches, different points of view, and different worlds. I included fragments motivated by problems in the sphere of mathematical physics, and many of them are also linked to problems in number theory. In other words, this research project is not like a snake in that we go from A to Z through B and C. It's more like an octopus – we have some findings, some ideas, and we try to cause them to spread in different directions.

Such projects must be difficult to coordinate.
That's true. Forming a team to work on the project may therefore prove quite complicated. But I'm simply trying to find scientists that have different interests and different qualifications.

You've received the ERC grant to form a research team, among other things. Where are you planning to implement your project? What will your work involve?
I'll be implementing my project here, at the PAS Institute of Mathematics, by leading a team of researchers for five years. How do I imagine doing that? Mathematicians work a bit differently than physicists in that they typically work alone. Even if they're writing a paper together, most of the work is not done when they're together. This means that our teams don't have a typical, hierarchical structure; nor do they have specific tasks to perform, for example to prove a theorem, which can be done if it has already been stated. In our research, we usually pursue loosely defined directions. We can nudge people towards a certain direction, but most certainly not by giving them official instructions.

In social sciences, studies of what we don't know are referred to as exploratory research. Could your projects be described in this way?
I'm not sure about that. In mathematics, every research project is in a sense exploratory, because we can only sense what is true. Incidentally, that's a very interesting topic – mathematics is an exact science

that has exact proofs, but how do mathematicians know that a theorem is true before they start trying to prove it? How do they know something is true? They're helped by intuition, which they start developing around the time they obtain their doctorates. That's what we're investing this money in.

Does this mean that in very simplified terms the ERC grant will give you and your team the comfort to consider certain problems, follow your intuition? Does new quality in your field not emerge in the course of discussions?
Mathematicians have two modes of operation. First, they talk to people, absorb certain ideas, and read. After that, they sit down in a room and think.

Can you see any people around you that could help you on the project?
There are currently not too many people in Poland who do I what I do, but I think that my team will be partially Polish. Thanks to a grant from the Simons Foundation for the organization of thematic grants, the Institute is visited by many people from other countries.

You also studied abroad. What would you say about this experience? Is it possible to compare the University of California, Berkeley, and the PAS Institute of Mathematics?
It's hard to say. As for the scientific level, the Institute in Warsaw is not bad. It has a better library – there's really everything there. Nevertheless, there is a huge gap between these two institutions. In the United States, I studied at a very big department that had over 100 doctoral students, so it was very active.

One of the problems faced by the Institute of Mathematics is that the staff teach no courses, so there's no motivation to come to work. Mathematicians need their heads and a piece of paper to work – they don't need an office. If someone works better at home or in a café, that poses no problem. But this translates into a specific work culture. It's rather empty in here, and that's somewhat demotivating. There's a huge contrast, not even in terms of Berkeley, but also between the PAS and the Faculty of Mathematics at the University of Warsaw.

Does this mean that you suggest the introduction of teaching?
No, I absolutely do not suggest anything. But people who visit here from other countries are very surprised that there is a PAS institute that employs a lot of people yet teaches no courses.

You've mentioned a huge gap between the places where you've worked. Does it result from the fact that the people there keep tripping up more than the people here, that there's less of a mixture of ideas and fewer things are done together? What is needed to bridge this gap?
More cash.

Did you have a chance to work in other foreign countries, apart from the United States?
Yes. I spent a year in Bonn. Also, I worked as a postdoctoral researcher at IHES outside Paris. It's also a purely research-focused institute, but it works more like the Institute for Advanced Study in Princeton, which has few permanent staff members, but many people come there under contracts. I enjoyed working there very much.

Is the gap between Poland and Germany and France as huge as the one between Poland and the United States?
Yes, Paris and Bonn are Europe's most important mathematical centers, and a lot is happening there. Many people come there. When I read a scientific paper there and find something I don't understand or have an idea, I can write the author and it often turns out that this person is in Paris this week, and we can meet. This doesn't happen very often in Warsaw. There are very few people here I could talk to.

> Anyone pursuing a career in science in Poland is already truly motivated and doesn't need additional encouragement. Rather, we should try not to make their job more difficult.

Apart from financial issues, do you have any systemic suggestions that could improve the situation of Polish scientists?
Yes, please write in your interview: "Dr. Achinger takes out the Polish Young Academy's report on consultations about the problems at the PAS units (amu.pan.pl)." (laugh)

Is this question answered there?
No, but I agree with the recommendations made by the Polish Young Academy. As for the Polish Academy of Sciences, I'd pay more attention to how competitions are organized and how remunerations work.

So we're back to the issue of motivation.
If someone in Poland pursues a career in science, this means that they're already truly motivated. They don't need to be additionally encouraged. Rather, we should not make their job more difficult and judge them. For example, requiring scientists to have a specific number of publications in journals from a specific list will not suddenly cause them to write better papers.

Your career is impressive. Did you plan and imagine it this way?
It's hard to write a grant application by accident, that takes a lot of work. That's somewhat frustrating, because that's time taken away from research. But it can't be done in any other way. I initially thought that an ERC grant was not for me. But then I proved an interesting theorem that I found important. The grants work in such a way that you need to have an idea for something groundbreaking, and you need to be able to prove it. Finally, I had the hunch that I had a chance to use something like this to support my idea. And it worked. I'm very pleased with that.

> Learning without a set purpose is very important. Sometimes something ostensibly purposeless may bring a lot of good.

However, it's hard to plan your career in a completely conscious manner, because scientists apply all the time. In the United States, scientists who have received their doctoral degrees apply for postdoctoral fellowships in a hundred places. They never know if they'll be lucky enough to end up at Columbia, or maybe at the University of Kentucky.

How do doctoral researchers earn their living when they're busy applying for a hundred grants?
In the United States, filing applications is easier, because there's a computer system of job applications. You need to have letters of recommendation and research plans, but after you adjust them to the criteria of specific institutions, the application process gets easier. But I also talked to people who obtained their doctorates in the 1990s, and they submitted their applications manually. They'd spend several weeks putting their applications into envelopes and sending them out to a hundred places. So that's what a conscious career looks like – you apply for everything, and if you get a yes, you can start thinking about what happens next. I was very lucky. When I was filing my applications, the United States was in the grip of a financial crisis. The first one was rejected, but with the second one I already had funding thanks to a Fulbright grant (in the program "Science & Technology," which unfortunately no longer exists). That's probably why it worked.

Finally, what role do you think mathematics plays in the modern-day world? We're fascinated by new technologies, but we often forget that everything starts with mathematics. Do you think that your research could be somehow adapted in solutions in the field of new technologies?
In my research, I'm not motivated by new technologies at all. But in basic research, everything can be applied somewhere. That was the case with number theory. The most prominent mathematicians studied the divisibility of numbers and similar things, but there was no motivation from other sections of science. On the other hand, many things that people do on a daily basis are served by encryption algorithms based on elliptic curves, and that's something people have studied for a long time. In the 19th century, for example, Bernhard Riemann studied completely abstractly interesting geometric objects. That's an excellent example, because it was linked on the one hand to arithmetic and number theory and on the other one to physics and string theory. At the same time, that found surprising applications in cryptography.

Does an advanced knowledge of mathematics help you solve everyday problems?
Yes, for example it puts food on my table (laugh). But no, I don't think it helps me in any direct way.

You nonetheless work with young people...
I collaborate with the Polish Children's Fund, which gives stipends to talented young people from the whole of Poland, with a particular focus on places where the reach of science is more limited. I also organize various events for the young people I tutor. I often teach workshops in advanced mathematics, and I'm often surprised by the high level of the participants. These are very young people, for example in middle school, and they can ask questions that stump me. I'm very pleased when this happens. When I was in high school, I was not helped by the Fund, but many prominent mathematicians were. I believe that such supports impacts more on the development of young talents than math competitions. It allows them to learn without a specified purpose. I believe that's very important. Sometimes something ostensibly purposeless may bring a lot of good.

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