The man who calculates

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Artur Ávila, a Rio de Janeiro-based specialist in a field called dynamical systems in which the objective is to develop a theory capable of predicting the long-term evolution of natural and human phenomena, received the Fields Medal, the most important international mathematics award, on August 13, 2014. At 35, he became the first Brazilian and South American to be granted such an honor, which is given every four years by the International Mathematics Union (IMU) to researchers under 40. In addition to Ávila, who works at the National Institute of Pure and Applied Mathematics (IMPA) in Rio de Janeiro and is head of research at the National Center for Scientific Research (CNRS) in Paris, the medal was also awarded to the Austrian Marnin Hairer, the Canadian Manjul Bhargava, and the Iranian Maryam Mirzakhani, the first woman to win the award. Of the four winners, who also received €10,000 in cash, Ávila was the youngest. "For the other candidates, this was the last chance to win the medal because of the age limit. Due to circumstances at the time, I thought I had little chance of being recognized this year," Ávila said in an interview in Rio de Janeiro, after traveling to Seoul to receive the award at the 27th International Congress of Mathematicians.

The excellence of this Brazilian, who also gained French citizenship last year, manifested itself early. The only child of divorced parents (he has a half-sister through his father), he had a middle-class upbringing and attended good schools. In 1995, at the age of 16, Ávila won the gold medal at the International Mathematical Olympiad. Two years later, while

AGE 35

SPECIALTY
Dynamic systems

EDUCATION
Federal University of Rio de Janeiro (UFRJ) and National Institute of Pure and Applied Mathematics (IMPA)

INSTITUTION
IMPA and National Center for Scientific Research (CNRS), Paris

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still a student at the traditional Santo Agostinho High School and without having enrolled in a university, he completed a Master's degree at IMPA. In 2001, at the age of 21, he finished his Doctorate, also at IMPA, along with an undergraduate degree at the Federal University of Rio de Janeiro (UFRJ). "Smart students usually like to show off and ask many questions," says researcher Welington Celso de Melo, Ávila's PhD advisor. "Arthur was different. He did not talk much, but when he asked questions I was unable to answer them immediately. I would have to go home and think about the answer."

Married to a researcher in economics, with no children, Ávila lives in both Paris and Rio de Janeiro, the two cities that let him do what he likes best: solve big mathematical problems. Among his achievements are solutions for the Schrödinger operators, mathematical tools that help describe the evolution of vector states in quantum systems. Even before winning the Fields Medal, Ávila, who has over 50 published papers, enjoyed enormous prestige in mathematical circles. His way of conducting research is unusual. He does not read much, he does not teach, and he can work at home, in his office, or even on the beach if he is in Rio. He prefers to learn a new research topic by establishing partnerships with colleagues who are specialists in the field in question. "You are talking, and the person explains what is most important. You do not necessarily need to read all of the literature on a problem," he said. Averse to interviews, Ávila says he has no vocation for communicating mathematics to the general public, a duty that will be difficult to avoid after receiving the greatest international award ever granted to a Brazilian researcher.

It is true that, unlike the Nobel Prize, the Fields Medal winners are notified in advance that they were chosen to receive the award?

We knew before the announcement. I knew five months in advance and had to keep it secret. It was a long time, but I contained myself.

Your name was already under consideration to receive the medal four years ago. Did you expect to win the award this time?

I didn't expect to win this time due to the existence of another strong candidate in a similar subarea and the fact that I was younger than the other candidates. I still had one more chance and could win the medal in 2018. For the others, this was the last chance to win because of the age limit. Due to circumstances at the time, I thought I had little chance of being recognized this year.

Who was the other candidate in your subarea?

The Iranian Maryam Mirzakhani, who also won the award, was the other candidate. It was exceptional that they gave the medal to both of us. We work in neighboring subareas, and that made it unlikely that both of us would be honored in the same year. For this reason, and because it was the last chance for her but not for me, I thought that I would not win.

Have you and Maryam worked together?

No. However, I have worked with people who have worked with her. She has already used results from my work and vice-versa. She works in a subarea that intersects with mine, and we have common interests. So, we could work together in this subarea, and we are certainly working in the same direction with common co-authors. For some reason, we have never even met.

Normally, do the organizers of the award avoid giving the medal to mathematicians in similar subareas?

There are no rules. However, I understand that if there is a situation in which one candidate could wait four years until the next award, they might prefer to award the medal to people from a greater variety of subareas. It was what I would think and what could have happened to me. I could certainly have been a candidate in 2018, too. I was not in a hurry.

In 2018, the International Congress of Mathematicians will be in Rio de Janeiro. Do you think the choice of Brazil to host the meeting influenced your candidacy for the medal?

The decision on where to hold the congress is separate from the award committee decision. They are quite different issues. The meeting involves mathematical development questions and organization issues. The fact that Brazil has demonstrated its ability to organize major events helped its candidacy. Many countries that have hosted the event have never won a medal, such as South Korea, India and Spain. The medal is for recognition of mathematical research, a purely scientific issue. It is the first time a prize winner has completed all of his education through the doctoral level in a developing country, rather than in Japan, parts of Europe, the United States or Israel. I studied only in Brazil, and this did not hold me back. The quality of the PhD I did at IMPA was the same as whatever I could have done abroad. It is a clear demonstration of the quality of what can be done here in Brazil. This, of course, is due to the teaching and research IMPA has been carrying out for decades.

How did you see yourself at 21, finishing your PhD? Did you feel you were special because you were a prodigy?

I was younger than most PhD students. However, I knew that I could finish my PhD early but still not become a great researcher. You can be an excellent math student and have excellent grades but not have the ability to do research. Even if, in this context, you are able to do PhD research, you could have difficulty continuing in a research-oriented career. Sometimes, you cannot continue to produce the same quality of work. You could also not demonstrate any exceptional abilities at the start of your career, and then at some point things could click. That is how I saw things, and my goals were very basic. During my PhD, my goal was to perform research to obtain basic results. I intended to follow the normal path of a researcher when he wants a career, without lofty future goals. I had reasonable ambitions because I knew that obstacles could arise and probably would.

You started studying at IMPA very early. How did that happen?

That was because IMPA sometimes accepts younger students who are still in high school. They do this if they perceive that the student is able to do the work. I knew about this, and this aroused my interest in doing the same thing. This wish was granted when I returned from the 1995 International Mathematical Olympiad, at which I won the gold medal. IMPA suggested that I take one of the level 1 courses shortly before starting

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Fields Medal awards ceremony during the International Congress of Mathematicians in Seoul

the Master's degree. If everything went well, I would enroll. In fact, that is what I did while still in the last year of high school. I started at the Master's level, and after a while I continued on to the Doctorate more or less normally, taking courses at IMPA. At one point, I began to talk with researchers, with Welington, and that was how I got my start in the field of dynamical systems.

Why did you become interested in mathematics and not science?
I don't know. I always liked math, even before I understood the difference between the fields, since I was 5, for no special reason. I also liked other fields that I thought were science. But, in mathematics, you can advance much faster on your own and I had this contact with the mathematics Olympiads, which gave me encouragement and focus and also served to transition me to IMPA.

How did you become interested in dynamical systems?
I have certain characteristics as a researcher that adapt well to research in dynamical systems and that would also adapt to other areas. I am an analyst. I work with analyses, statistics, and geometry. In my case, I was more exposed to the area of dynamical systems because I was at IMPA and in direct contact with Welington. That is why I chose dynamical systems, where these characteristics are very important. You can treat this topic using these techniques or others. I like the area, but the choice of dynamical systems was due to the historical chance of my being at IMPA.

How would you explain the area of dynamical systems to a layperson?
In general, dynamical systems is the study of systems that change over time, with a rule that describes the transition from one moment in time to the next; between today and tomorrow, for example. This rule could be very simple. But, over a long period of time, you see complicated behavior emerging. We call some systems chaotic. The study of this chaotic behavior that emerges in the long term is one of the principal concerns in the area of dynamical processes. [The results and methods originating from the area of dynamical systems are used to explain complex phenomena in fields such as chemistry (reactions, industrial processes), physics (turbulence, phase transitions, optics), biology (species competition, neurobiology) and economics (growth models, financial market behavior).]

Superficially, people associate chaos with disorganization, but there are rules within the chaos, right?
We have become able to better describe good-quality chaotic systems, which have certain characteristics. They are sensitive to initial conditions, and in them, small changes create large effects. At first glance, on the one hand, it seems to be something that prevents us from saying anything useful about the system that destroys the possibility of forecasts. But, on the other hand, it introduces new rules that the system follows, new laws that can be used by the system. These laws are no longer deterministic but rather statistical and probabilistic. We then have to ask questions and try to give answers in terms of probabilities and system behaviors instead of having absolute certainty. We try to model the system stochastically [using a probabilistic description of the processes]. We try to treat the system in whatever way possible.

It is correct to think of the Sun and its planets as an example of a chaotic dynamical system?
In the planetary system, it is difficult to describe the emergence of chaos. This is still very complex and is not very well understood. However, an event in which chaotic phenomena appear could be due to the interaction of quadratic functions [second-order polynomials], which every child learns about in school. After a long time, what would be the effect of the repeated application of the same quadratic law? It could result in the emergence of chaos. This is a very simple example of what happens.

Some people say that you're a great problem solver, perhaps more so than a formulator of theories. Do you agree with this statement?
Many times in my career I have sought out known difficult problems and worked hard to solve them. Because I did this several times, it is certainly true that I solved many problems. But, to a lesser extent, I also worked on building and developing these theories, which sometimes involve not only solving but also formulating the problem. In the beginning, I resolved a problem related to Schrödinger operators, but later, I also constructed a theory and solved problems related to it. However, certainly, the most visible aspect of my work is my many solutions of dynamical systems problems in different contexts.

Your PhD advisor, Professor de Melo, said that you have always been very selective in your choice of projects and became interested in the great problems of mathematics, trying to avoid being sidetracked by smaller questions. Was that your strategy?
I work on things I like, with problems that particularly interest me, that I consider beautiful. Often, the problems

considered difficult are fundamental because some aspect of them is of great interest. Theories also develop around these problems. The mathematician is usually attracted by the richness of the theory around these objects. Working with these problems allows us to explore more pleasurable things. However, I do not discard a problem because others think it is not important. I also worked on questions that I knew would not have a monumental impact. I solve these simpler problems faster. I do not spend most of my time working on them because they can be solved quickly. They are simpler.

You did various projects with colleagues. Do you like to work as part of a team?
I mainly like it when I want to learn something. I do not tend to read.

What do you mean?
I read very few mathematics books and papers.

How can you do research like that?
In mathematics, you can advance without having a deep knowledge of the literature; it is more important to have a very precise understanding of the fundamentals. I learn these important things more easily by talking to other researchers. That is when collaboration is useful. You are talking, and the person explains what is most important. You do not necessarily need to read all of the literature on a problem.

Is this unique to you or do many mathematicians work this way?
It is not a completely unique characteristic. Mathematicians work in different ways. Some mathematicians like to read a lot. I do not. I know a lot because I have already solved many problems. I often begin to work in an area, doing research, even before studying the area. Before studying, I try to solve a problem. However, it is very difficult to start from nothing, without knowing anything. So, I begin a collaboration, and before I even learn a topic in depth, I have already solved an important problem; that motivates me more. I have changed subareas several times, and each time, I solved an important problem right away and only later understood what the theory said about that problem. It involves a bit of the technical characteristic of the person and their intuition, too. For me, it works.

How does intuition help the mathematician?
The most difficult parts of mathematical work are those that involve creativity, which lead to discovering things that are, obviously, different from the basic rules. Every top mathematician has excellent technical skills and can follow known paths without difficulty. This is certainly true in my case. What trips up research is having to go outside established methods, discover something and try to identify a way to attack the problem. Faced with the unknown, there is no rule as to how to approach something. You must rely on your intuition to decide how to attack a problem. This involves a bit of experience, which helps a lot in developing intuition on a topic. You go in one direction because you hope it will work, but you cannot formalize it mathematically yet.

Why did you become a French citizen?
I completed my PhD in Brazil and went to France in 2001. My first positions were in France, and I spent five years there before returning to Brazil. After that, I spent three years in Brazil, and then started spending half of my time here and half there. The time I spent in France complemented my training as a mathematician, and I extended my areas of research. I finished my PhD with the ability to conduct research at a high level. My results were recognized as important, but I had a restricted view of the area and its position within the whole of mathematics. In Paris, I had contact with the largest community of mathematicians in the world and unparalleled activity. This forced me beyond my area of expertise at the time, one-dimensional dynamics, and made me look for other things to be able to interact with these people who were not necessarily interested in the same things that I was. In this search with such good professionals, with so many possible co-authors, I started working in other areas, and my work was lauded due to what I did in these areas. The mathematician that I am today is a result of my time in France and my training in Brazil. Thus, I thought it was more accurate to consider myself a French-Brazilian mathematician. If I am a French-Brazilian mathematician, it makes sense to have French nationality too, which also leads to practical benefits for my life there.

What is your work schedule like, in Rio and Paris?
I go back and forth. I do not spend six whole months here or there, it is much more broken up. I spend some months there, others here. I try to avoid winter in Paris, but there are some exceptions. The details of the trips are decided at the last minute and, depending on the circumstances, I choose the specific dates. I have a great deal of flexibility because I only research and do not teach. It is one of my characteristics. I prefer to spend my time on research, and I do not think I have great teaching skills. I have PhD students, but basically, I do not teach. So, I do not have to follow a calendar, which I would have to do if I had to teach.

It is true that you wake up late and usually work more at night?
I certainly continue waking up late, at 11:00 or even at 13:00. However, this varies a lot. It depends on the previous day and on things that could be more engrossing. At night, I work before going to bed or, if I wake in the middle of the night, I can think about mathematics. However, I try to work in the afternoons too. I often work with colleagues and I am not going to work with them after midnight. I have worked in various situations. Most recently on the beach or walking along the beach, for example. Not so much at night.

Are your routines in Paris and Rio similar?
Not at all. To begin with, I do not have a set routine. There, I tend to go to my office more often. There is no beach there, of course. So I meet co-authors, colleagues and students. I try to have several meetings during the day, not necessarily in my office. Some days I stay at home, too. In France, this occurs more frequently. In Brazil, I usually invite people to meet me near my home. When I work alone, I tend to stay at home or go to the beach. I am not always working intensely. When I am not working on a very specific line of research or when I am a bit lost, unsure of how to approach a problem—which happens most of the time—working intensely doesn't help much, and there is no way I can work for many hours at a time. I don't work many hours a week then. It is different from some situations, which occur now

and then, in which I hope, know or imagine that something is going to work and involve a lot of technical but directed work. In these cases, I work very intensely, for many hours a day.

Brazil's math and science teaching is poor. Do you consider yourself an exception, given this?
I think that I am more a natural consequence of the evolution of science, especially mathematics, which is perhaps the most developed field in Brazil in terms of international impact. This is due to the inherent properties of mathematics but also to the people who work in the field. Mathematics depends more on human resources than on material resources. Having focused people can be enough to go far. When one depends on many material resources, such as laboratories, the will of the researchers will not be enough, no matter how competent they are. [Brazil's prestige is evidenced by the fact that there are currently four Brazilian voting representatives at the IMU general assembly, one less than powers like the United States and France. At the International Conference in Seoul, four mathematicians from IMPA gave talks.]

What could be done in the schools to awaken interest in mathematics?
Given my background, I did not have contact with teaching in schools. I went to very select schools, I went directly to IMPA and did not spend much time at a university. I formally attended a university, but I studied at IMPA. I did not have contact with the reality of teaching in Brazil. If I talk about education, it is more about what I imagine it is like. I do not teach at a university, so I do not have daily contact with that reality. I prefer to let other people who have more contact with and ideas on this topic discuss it. There are high-level mathematicians who have much better ideas about this that I do.

Another Brazilian at IMPA, Fernando Codás, has been mentioned in relation to winning the medal. What do you think of this possibility?
I think that Brazil and IMPA have been producing excellent mathematicians for some time. I am a bit reluctant to put pressure on any one person. It is not supernatural to win an award. What was considered impossible occurred. It occurred within a continuum of improvement in Brazilian mathematics. It is not a unique event that cannot be repeated. However, it really is a rare award. Not receiving it does not mean your research is of poor quality. I like to remind people that Germany—which has 100 Nobel prizes to Brazil's none—has only one Fields Medal winner. You can see how rare this award is. This does not diminish the quality of the research carried out by German mathematicians and their contributions in any way. You cannot measure things by these awards; it would create immense distortions. The analysis is much more complicated. With the medal, it is easy to show people that Brazil did something at the highest international level. Before, Brazil already did so, but it was harder to demonstrate it. People could even say "so, where is the award?" However, now they can't. However, things should not be measured in that way because that is not the focus.

The Fields Medal is a clear demonstration of the quality of the research that can be conducted in Brazil

Do you think that, from now on, you will be a sort of ambassador for Brazilian science and mathematics abroad?
Among mathematicians, IMPA was already well-known. So, it is not so important that I play this role. I think that to a slight extent, I have the role of helping promote mathematics to people who are not mathematicians and who do not know that we do high-level mathematics in Brazil.

Do you intend to give talks in schools?
I will probably do something along those lines, but the objective is to play this role alongside people who have more of a calling for it. I am very limited in various aspects related to explaining math to a more general public. It is not one of my skills. I already find it difficult to talk to non-PhD students in mathematics, even in my subarea. On the other hand, I have greater visibility. We still have not decided how we are going to reconcile this. However, in practice, due to my limitations, I will not be communicating directly with people.

But wouldn't it be natural for people to expect you to have greater contact with non-specialists?
They can ask, but I have a choice. I think I can do something positive indirectly. There are many competent people who communicate much better than I do. I do not need to be the person speaking. I can be next to him or her.

What is your life like outside of mathematics?
In Brazil, I try to go to the gym often and, when possible, to the beach. I live on Leblon beach. I like to walk in the neighborhood and do typical things, like going to juice cafés. In Rio, I have childhood friends with whom I maintain contact, and I organize get-togethers. Everything I do is very normal. I don't do anything very odd, no high-risk sports, no trips unrelated to mathematics. In Paris, I meet with a group of math colleagues after work and we go to bars and such.

Paris is famous for its cultural life, its museums. Do you go to these places often?
No. ■