Finanțat de Uniunea Europeană NextGenerationEU

Planul Național de Redresare și Reziliență

"PNRR: Funds for a modern and reformed Romania!"

Interview with **Mr. Maxim Chernodub,** *Senior Researcher*

Dear Maxim, we appreciate your participation in this interview. Let's start by sharing some details about our center. The Counseling and Guidance Center for Research Careers aims to inspire youth to explore research careers and foster an interest in Romanian research within the community. These interviews are designed to demystify the realm of science for those who may find it challenging to grasp its significance in our daily lives. Additionally, our objective is to provide role models for young individuals keen on embarking on a research-oriented career. We are excited to learn more about you and your career in research.

1. Tell us about yourself. How would you describe yourself as a person and as a researcher?

I am currently working at the Institute Denis Poisson, a research unit shared between the University of Orléans and the University of Tours in France. The institute primarily focuses on mathematical sciences. However, it has significant research divisions dedicated to high-energy physics, particle physics, gravity, and integrable systems. In addition to my work in France, I am directing a group at the West University of Timișoara, where our research concentrates on the complex properties of quark-gluon plasma.

Describing oneself is indeed a challenging task. I am passionate about physics and dedicate most of my time to academic research, whether I am in Romania or France. My work is predominantly theoretical, encompassing both paper-and-pen analytical and computer-based numerical calculations. The latter often requires the use of advanced supercomputing resources to model physical systems based on the first principles of the theory. My devotion to understanding the fundamental aspects of the Universe drives my research and academic activities, sometimes at the expense of my personal life.

2. How did you start studying quantum physics?

As a schoolboy, I never anticipated that I would work in the field of quantum physics. My initial interest was firmly rooted in chemistry, as I was captivated by various substances' fascinating chemical reactions and remarkable properties. However, it became evident over time that a deeper understanding of chemistry inevitably requires the use of the foundational principles of quantum physics that govern atomic and molecular behavior.

Indeed, the properties of chemical elements are set at the quantum level, which determines the structure of electronic shells around an atomic nucleus. This realization that the quantum properties of atoms, molecules, and ions underlie all chemical phenomena naturally redirected me to the study of quantum mechanics. Basically, when you get to the bottom of things in chemistry, you face quantum physics. My curiosity made me an offer that I could not refuse: I left chemistry and started to study quantum mechanics. Now, I am working on quantum field theory, which offers a more advanced approach to nature than quantum mechanics.

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3. Could you please share your thoughts on your experience at West University of Timișoara and your time in Romania so far?

When you travel to a new country for the first time, you never quite know what to expect. It was precisely my feeling, mixed with curiosity when I flew to Timișoara a year ago. My task was to start establishing a research group focused on one of the most advanced fields of study: exploring the properties of the hottest and most vortical plasma ever created by humanity. The support for the group came from the European Union - NextGenerationEU project, funded by the Romanian Ministry of Research, Innovation and Digitalization through Romania's National Recovery and Resilience Plan.

Upon my arrival, I met my colleagues from the West University of Timisoara, Dr. Victor Ambruş and Dr. Cosmin Crucean, with whom we immediately became good friends. I encountered brilliant scientists with whom I shared the same scientific interests and principles in life and who faced the same challenges in science. So, I quickly realized that the project already has an active core team of senior scientists.

Together, we started to recruit junior colleagues, including postdoctoral fellows, graduate students, and master's students. I was pleasantly surprised by how swiftly our scientific endeavors began to merge, assembling a productive group. Today, we are a well-coordinated team, and I am immensely pleased with our progress. Moreover, we are an international team: at the moment, the members of the group who are already working in Timișoara include Indian, Spanish, and Italian postdoctoral fellows, with more to come.

One of our Romanian PhD students at the West University of Timişoara also became enrolled in a PhD program at the University of Tours, France. The student will follow a double diploma program, also known as "cotutelle" in French, which is an academic arrangement where a doctoral student is jointly supervised by two institutions. This international program allows the student to simultaneously receive two doctoral degrees (in this case, in Romania and France) and get a broader academic and cultural experience.

However, some challenges persist. If I were to describe these challenges in one word, it would be "time"— or rather, the lack of it. Time is a scarce resource, which can easily be consumed by administrative tasks. Beyond our scientific work, we are also occupied with grant reporting, organizing a leading conference in our field in Timișoara at the end of July, and handling the extensive paperwork involved in building our team. Fortunately, we benefit from the indispensable support coming from the administrative departments of the West University of Timișoara, in particular of our financial administrator, Ms. Nicoleta Delia Ivanovici, whose administrative assistance is simply invaluable. Without this support, the smooth operation of our academic group would be unimaginable.

Despite the perpetual issue of lack of time, our scientific progress is ongoing. We are writing multiple research papers, some of which have already appeared as publications in prestigious international journals. Equally important is the positive psychological atmosphere within our group. The supportive academic environment and robust administrative backing from the University have made my experience in Timișoara overwhelmingly positive.

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4. What are you currently studying? Could you please explain?

Here, we should start from the very beginning, namely, from the Big Bang. This term is used as a "creation" event in mainstream cosmological theory, which aims to describe the origin of our Universe. The theory states that the Universe began approximately 13.8 billion years ago from an extremely hot and dense singularity. During its evolution, the Universe rapidly expanded and cooled, leading to the formation of matter, galaxies, and all cosmic structures we observe today.

In one of the earliest stages of the expansion, the space was filled with the ocean of the first-ever fluid, which was made of quark-gluon plasma. This state of matter ---that existed in the first microseconds after the Big Bang--- is the topic of our research.

Quarks and gluons are fundamental particles that comprise protons and neutrons, which, in turn, form the nuclei of atoms. Both quarks and gluons are tightly bound within nuclei due to a phenomenon called color confinement, which implies that these elementary particles cannot be observed as isolated entities outside of nuclei under ordinary conditions. In contrast, the primordial quark-gluon plasma phase is believed to be a hot, dense state where quarks and gluons are deconfined as they are free to move independently, forming a kind of hot 'soup.'

Nowadays, the quark-gluon plasma is routinely created in ultra-relativistic collisions of nuclei of heavy atoms. The heavy ions, for example, of gold or lead, are accelerated to velocities close to the speed of light and then sent on a collision course toward each other. When ions collide, they form the plasma with temperatures above two trillion degrees Celsius, or roughly a hundred thousand times hotter than the sun's center. This is the hottest state of matter that humans have ever created.

The lifetime of the created plasma fireball is very short, about one yoctosecond (one septillionth of a second, or one trillionth of one trillionth of a second). However, even during this very short time, the plasma can tell us, scientists, many fascinating stories about the first-ever primordial ocean that once filled the whole Universe a long time ago.

These intriguing experiments are taking place at the Large Hadron Collider at CERN in Europe and the Relativistic Heavy Ion Collider at Brookhaven National Laboratory in the United States. They help us probe the strong force—one of the four fundamental forces of nature—and explore conditions that are believed to once existed at the beginning of our Universe and that cannot be replicated elsewhere.

Now, let us imagine that heavy ions collide slightly off-center, resulting in the formation of a rotating plasma. A non-central collision creates what is known as a "vortical" plasma because the rotational motion introduces vorticity, a measure of the spinning motion of the fluid. The quark-gluon plasma created in these collisions can spin faster than anything else humans have ever made: the rotational velocity would correspond to a milliard of trillions of revolutions per second.

Due to their rotational motion, vortical quark-gluon plasmas generate intense magnetic fields that were recently measured to reach millions of trillions of the Earth's magnetic field. Additionally, rotation of the plasma can induce spin polarization of particles such as quarks. In more detail, if one speaks in simple terms, one can imagine a spinful particle as a tiny top that turns rapidly around its axis, and the spin of the particle can be thought of as a result of this rotation. Spinful particles in plasma tend to align their tops along the axis of rotation, and this effect, "spin polarization," can be measured in the experiment.

Furthermore, plasma rotation can impact how fast it cools down with expansion, as rotating and non-rotating plasmas behave differently. The investigation of these effects is one of the central aims of our project, which allows us to delve deeper into the fundamental behavior of matter under extreme conditions.

*By the way, the short name of our group is FORQ. This is not the tableware that we usually use during meals, but something more exotic. The name comes from "**F**acets **O**f **R**otating **Q**uark-Gluon Plasma", which describes the center and "entourage" of our interests.*

5. Are there potential practical or technological applications that could derive from this theoretical research?

Of course, investigation of such exotic substances as quark-gluon plasma can help us understand one of the earlier states of our Universe. However, I imagine that nobody in the world has any idea of any technological application of quark-gluon plasmas at the moment. To say slightly sarcastically, despite this hot state of matter being described by quantum field theory, there is little chance that it can nowadays be used, say, in agriculture, which, in a certain sense, has something to do with the fields as well.

However, one should remember that in numerous cases, research ignited by pure academic curiosity led to totally unexpected breakthrough applications that went much beyond what their inventors could ever imagine. The simplest example of this kind is the invention of the laser.

When lasers were first developed in the 1960s, they were often dubiously described as "a solution looking for a problem." Their practical uses took time to become apparent, and at the time of their invention, they were skeptically seen as a scientific curiosity rather than a technological breakthrough. Now, our lives are highly shaped by the invention of lasers, which are ubiquitous and essential in various fields, from medicine and manufacturing to communications and consumer electronics.

Who knows, maybe sometime in the future (say, in the early 2300s), vortical quark-gluon plasmas may be used in cores of antigravity reactors of spaceships?

6. What are the major challenges currently facing your field of research?

There are many physical processes and phenomena that we still need to understand in our area of research. For instance, we have no idea of the origin of color confinement, which implies that quarks and gluons aren't observed as elementary particles (quarks always come together so that they are "confined" into specific states, called hadrons, but quarks cannot exist alone without being accompanied by two other quarks or by its antiparticle, an antiquark). Can we derive color confinement from basic principles of theory?

We also need clarification on how quark-gluon plasma rotates. Recent observations suggest that plasma might have a negative moment of inertia, but this controversial phenomenon remains uncertain. Additionally, we seek to understand the phase diagram of plasma, precisely how much energy is needed to transition matter (or vacuum) into the plasma state, and how rotation influences this process. The questions and challenges that we are facing are endless, which drives our curiosity further and further.

7. Who are the mentors or role models that have impacted your research career most?

Difficult to say: my research is shaped by interacting with many people from different fields in our scientific community.

8. What advice would you give to young researchers interested in pursuing a research career?

If you have an exciting but seemingly ridiculous idea that you still believe is right, pursue it, justify it, and don't be afraid to publish it. Quite often, such ideas become the foundation for major academic and technological breakthroughs in the subsequent decades.

We sincerely thank you for your time! We wish you great success in all your research projects!

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Produced and Edited by: Counseling and Guidance Center for Research Careers - Western Region

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