The MATH+ “Hanna Neumann Fellowship”

Hanna Neumann Fellow 2024: Interview with Zahra Mokhtari

[The Interview was conducted online in January 2024 by Beate Rogler, Public Relations Manager at Math+ ,and released on 12 May 2024, the International Women in Mathematics Day.]

Zahra Mokhtari has been a postdoctoral researcher at Freie Universität Berlin in the Department of Mathematics and Computer Science since 2020. She grew up in Iran and studied Physics in Teheran before moving to Vancouver, Canada, where she completed her master's in Physics in 2013. She then pursued her doctoral studies at the Institute of Theoretical Physics at the University of Göttingen under the supervision of Annette Zippelius, earning her PhD in Statistical Physics in 2018. Since 2019, she has held the postdoctoral researcher position at Freie Universität Berlin, collaborating with Felix Höfling since June 2020, where she continues her research in the field of non-equilibrium stochastic many-body systems. The research group has developed an agent-based model for path formation in ant colonies based on non-reciprocal coupling to a secondary field. This work diverges from the models typically studied in the literature, laying the groundwork for the current MATH+ project EF4-10.
Personal homepage

Interview:

The Fellowship awarded to you by MATH+ is named after the mathematician Hanna Neumann. Are you familiar with Hanna Neumann?
Hanna Neumann was a German mathematician who was forced to flee her country. She displayed bravery by not remaining passive or silent in the face of the atrocities committed by the Nazis against minorities at the time, even at the cost of losing her job. Neumann made valuable contributions to the field of group theory. Additionally, she was the mother of five children, a fact that is particularly remarkable. Nonetheless, she persisted passionately and professionally in her research, which was very inspiring for me.

What significance does this award hold for you?
This award holds two significant aspects for me. Firstly, it enables me to collaborate with scientists whom I have long desired to work with, collaborations that would otherwise be quite challenging to establish. Secondly, mathematicians’ acknowledgment of my work as a theoretical physicist through this award brings me joy. To some extent it is approval for my ability to communicate in their language.

When and how did your interest in physics and mathematics develop?
From my early childhood, I was always interested in measuring, counting, and finding patterns. I vividly recall being astonished by the circular motion of a spinning top and noticing similar patterns in the orbits of planets around the sun. As a child, I contemplated the circular nature of planets and

carousels, sensing a commonality between them without fully understanding it. Now, I recognize that these recurring patterns can be explained by similar principles. Moreover, in school, I was fortunate to have an innovative and inspiring teacher who sparked my passion for theoretical physics, leading me to pursue it as my major in university. I was also interested in mathematics because of its close relationship with theoretical physics. And finally, I was fortunate to have supportive parents who encouraged my interests.

Do you have any female role models?
Not particularly. What matters most to me is perseverance in life, not giving up in moments of despair; it's genuinely crucial for me. I deeply admire all women, especially those from the global south, who confront gender and ethnic discrimination daily. In moments of frustration, I often draw strength from these people, reminding myself not to give up and to persist in advancing both my career and my life.
Regarding female scientists, Maryam Mirzakhani is undoubtedly someone I admire. She was also Iranian, coming from the same school as I did, though much earlier. At my school, her portrait was on the “Wall of Honor” reserved for those who had achieved notable success during their school time. She was a female scientist whom I looked up to because I knew she had faced significant challenges to reach the pinnacle of her field. Tragically, she passed away from cancer at the young age of 40. Her persistence is the quality that resonates with me the most—not giving up even in the face of a life-threatening illness and striving relentlessly to achieve your goals, making the world a better place.

What does mathematics mean to you?
Mathematics has been a powerful tool that I use to describe and articulate my physical observations. Theoretical physicists, like me, rely heavily on mathematics for this purpose. Personally, I see mathematics as lying between art and logic, both of which are intrinsic, fundamental, and crucial to humanity. Just as logical reasoning, critical thinking, and artistic expressions are essential skills taught to everyone from a young age, mathematics should also be universally accessible. It's vital for individuals to possess at least a basic proficiency in mathematics, much like their ability to think critically, logically, and express themselves artistically.

Did you face significant challenges or receive substantial support while pursuing your career as a mathematician?
During my PhD in Göttingen, there were few women in theoretical physics. For instance, on the fourth floor of our institute in Göttingen, I was the only woman, which was sometimes challenging. However, the main challenge was being an immigrant here in Germany because my residence permit was always only valid until the last day of my contract. So, renewing my temporary resident permit was very stressful for me.
Another challenge was becoming a mother, especially during the time of Corona due to the closure of the daycares and the lack of family support. The workload was also quite demanding, requiring me to stay up late at night to finish tasks. However, I had mentors who were very supportive both during my PhD and postdoc, and I greatly appreciate that.

What advice would you give to young people, especially women, who want to pursue their career in mathematics?
I suggest joining large lab groups and focusing on building a solid network from the early stages of your career. In particular, one should resist the imposter syndrome, which is very common among

women in science. When you experience feelings of inadequacy or doubt your worth, it's essential to recognize that these are internal struggles. From an external perspective, you are likely performing well. Many women in science, including myself, have faced this challenge. Therefore, young women should be aware of this and not let it undermine their confidence.

Regarding your research: How would you explain your current research to non-experts in an understandable manner? Have there been any notable achievements?
Imagine certain animals communicating indirectly. Instead of visually tracking each other, they follow trails left behind, such as sheep following footprints in mud or ants following pheromones to locate food sources or nests. So, the question is, when observing large groups of these animals, do they collectively form patterns? We see this in nature, such as ants forming robust long trails. As theoretical physicists or mathematicians, we aim to describe these patterns using simple rules, here for example the rules being that the ants move at a constant speed and react to pheromones they encounter. We then translate these rules into mathematical equations and compare them with observations. In one of our early achievements, we found that specific rules programmed into our simulated animals successfully reproduced these trails. Thus, we can infer that these rules or mathematical equations represent one possible mechanism by which ants communicate. However, there may be other models that could also describe this behavior.

How does the concentration of pheromones influence the outcome?
The concentration of pheromones is a parameter in our model that we can adjust. We have the flexibility to increase or decrease it as needed.

Are there collaborations with animal behavior scientists who can add information and enhance the understanding of the communication methods?
We incorporate information from papers by entomologists to determine specific values for parameters in our model, such as pheromone concentration and ant speed. In recent years, there has been a growing connection between biology, physics, and mathematics. However, although ants serve as a good example of our model, we do not claim to describe these systems exclusively, rather we aim to study a more general set up.

Most aspects of our daily lives rely on mathematics and its integration with other disciplines. What role do you envision mathematics playing in the future?
I believe that mathematics will continue to serve as the foundation of science and various other fields, particularly with the growing prominence of data-driven language models and decision-making algorithms. The applications of mathematics are becoming increasingly essential, evolving into the backbone of both technology and science. This integration is becoming more inseparable, and will likely continue to deepen in the future.

What is your relationship with MATH+? And what do you consider the most significant challenge and advantage of such a vast and comprehensive research center?
I am a postdoctoral fellow funded by MATH+. If I were to highlight a challenge, it would likely involve maintaining global relevance and staying at the forefront of sciences amidst the diverse output of research activities. However, the most significant advantage lies in the interdisciplinary projects fostered by MATH+. These collaborations lead to amazing innovative projects that push the boundaries of science, which can fulfill the center's primary objective.

Additionally, I appreciate the various events organized by MATH+, such as Cluster Days, the MATH+ Friday Colloquium, and Spotlight Talks. Another advantage is its excellent support and much funding for young researchers and initiatives promoting gender diversity.

Finally, what are your plans for the Hanna Neumann Fellowship?
I have been in discussions with a professor in France, and we are planning to meet in both Berlin and France. In April-May, I will visit him in France. We have also begun outlining a potential research project that I will pursue.

Can you elaborate on the topic of this joint research project?
Certainly. The focus of this research project aligns closely with my current work, which I have explained before. We aim to investigate how sheep move within groups across landscapes. While these groups typically follow a designated leader, the research group I'm going to collaborate with has proposed a novel model for their motion. They suggest a temporal leadership structure, where sheep follow one leader for a period before transitioning to another.
From the mathematical point of view, they have demonstrated that this model closely mirrors real-world observations of sheep behavior. This concept emphasizes the role of temporally selected leaders, akin to sheep 'playing dice' to determine their next leader to follow. It's a sort of selection but determined by stochasticity. I am excited to work on developing a mathematical model that includes this stochasticity and accurately reproduces natural data.

Thank you very much for the interview, which included much personal information and insight into your research! We wish you good luck with the research project supported by the Hanna Neumann Fellow Award.