Ciprian Manolescu Interview

Conducted by Alexander Diaz-Lopez

Ciprian Manolescu is professor of mathematics at the University of California, Los Angeles, working in topology and geometry. He is a winner of the Morgan Prize and the European Mathematical Society Prize, a Fellow of the American Mathematical Society, and an invited speaker at the 2018 International Congress of Mathematicians. He is the only person to achieve three perfect scores at the International Mathematical Olympiad.

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Diaz-Lopez: When did you know you wanted to be a mathematician?

Manolescu: As a kid I liked math puzzles and games. I remember being particularly fond of a book by Martin Gardner (in Romanian translation). In middle school, I started participating in math olympiads, and by then I figured I wanted to do mathematics in some form when I grew up. At the time I did not know any research mathematicians personally, but I read a couple of books popularizing mathematical research and news articles about Wiles' proof of Fermat's Last Theorem. It all sounded very exciting.

Diaz-Lopez: Who encouraged or inspired you?

Manolescu: My parents have been extremely supportive, and I was fortunate to have good teachers—especially my high school math teacher Stefan Alexe, who lent me a large part of his collection of problem books to prepare for the olympiads. Clearly, however, my greatest mathematical debt is to my college and PhD advisor, Peter Kronheimer. We had weekly meetings for several years, and I learned a great deal of mathematics from him.

Diaz-Lopez: How would you describe your work to a graduate student?

Manolescu: I work in topology, where the main motivating problem is the classification of smooth shapes (manifolds). There is a theorem that a complete classification is not possible in dimensions four or higher, because we run into group-theoretic difficulties. However, one can focus on manifolds with a reasonable fundamental group, and then the problem becomes tractable in dimensions five or higher. Dimensions three and four are the interesting ones. In dimension four, most questions are still open, but (starting with the work of Simon Donaldson in the 1980s) there has been steady progress on this topic, using gauge theory. Mathematical gauge theory is the study of a certain kind of partial differential equations (Yang–Mills, Seiberg–Witten) that originated in theoretical physics. My research focus is on Floer homology, which is a way of capturing the gauge-theoretic information for a three-dimensional manifold. The ultimate goal is to understand four-dimensional manifolds, and Floer homology tells us something about what happens when we cut the four-dimensional mani-

Figure 1: The unknot detection algorithm based on knot Floer homology starts by representing the knot by a grid diagram: an n -by- n grid with one O marking and one X marking in each row and in each column, such that if we join the O s to the X s by vertical and horizontal arcs (with the vertical arcs on the top), we obtain the knot. The figure above shows how to transform a planar projection of the figure-eight knot into a grid diagram.

fold along a three-dimensional one. Floer homology also has applications to three dimensions per se, and to knot theory. For example, with my collaborators Peter Ozsváth and Sucharit Sarkar, we used Floer homology to describe a new algorithm (see Figure 1) for detecting when a tangled-up piece of string can be unknotted (without breaking it).

Díaz-López: *What theorem are you most proud of and what was the most important idea that led to this breakthrough?*

Manolescu: The disproof of the high-dimensional triangulation conjecture. The question of whether all manifolds can be triangulated was raised by Kneser in 1924. The work of Andrew Casson (based on that of Mike Freedman) in the 1980s provided counterexamples in dimension four. In dimensions five or higher, the question had been reduced (by David Galewski, Ronald Stern, and Takao Matsumoto) to a different problem, about the three-dimensional homology cobordism group. Thus, one could hope to use the techniques of gauge theory to solve it. I knew about the problem for a while, but I only started thinking about it seriously in 2012, and it came to my attention in a roundabout way. I had an idea about how to construct a version of an invariant of Casson's, and I was asking other mathematicians about what kind of applications one could hope for from such a construction. Several mentioned the triangulation problem, as something that Casson's invariant helped solve in dimension four but not in higher dimensions. It soon became clear that the version I had in mind would be of no help with this question. Nevertheless, I then became curious about what kind of invariant one needs in order to solve the problem. I remembered a different invariant from the literature, due to Kim Frøyshov, which came closer to what was needed. After some thought, I realized that if one incorporated into the picture a further symmetry of the Seiberg-Witten equations, based on the non-abelian group $\text{Pin}(2)$, then one could solve the triangulation problem.

Díaz-López: *What advice do you have for graduate students?*

Manolescu: Choose a good advisor, by talking to the older students and asking them about their experiences; also, find out what kind of jobs the past students of each potential advisor got after graduation. Pick a subfield of mathematics that you enjoy and try to specialize early in

grad school, so that you have time to write a good thesis (and maybe a few other papers). Start attending the research seminars in your area as soon as you can—even if you don't understand the talks, just getting an idea of what people are working on is helpful. At the same time, after you decide on your field, do keep learning mathematics in other areas. This will help you in the future, as many fruitful projects come from making connections between different parts of mathematics. With regard to writing your thesis, keep in mind that it is normal for it to take a long time; the transition from solving homework problems to doing research is difficult for everyone.

Díaz-López: *All mathematicians feel discouraged occasionally. How do you deal with discouragement?*

Manolescu: There are a few types of disappointments that appear regularly in a mathematician's life. The first is when you cannot solve the problem you're working on. It is then good to remember that this is expected—perhaps the problem just cannot be solved with current techniques; the miracle is when you solve it! The second type is when you think you solved a problem, you start writing it up, and then you run into a technical difficulty, which might invalidate the whole thing. This happens to me quite often, and it is disconcerting to think that all the previous work I did on a project could be in vain. However, so far I've almost always managed to solve this kind of issue, after some more work. By now I know that if something looks like a technical but not a fundamental difficulty, it probably is—so I should just be pushing harder to overcome it.

Díaz-López: *You have won several honors and awards. Which one has been the most meaningful and why?*

Manolescu: The Prize of the European Mathematical Society, which I received in 2012. It came as a nice surprise, at a time when I was getting bogged down in some long and technical research projects. The prize gave me the courage and confidence to think about some other fun problems on the side, including the triangulation conjecture—which I disproved eight months later.

Díaz-López: *Is being the only person to achieve three perfect scores at the International Math Olympiad a close second?*

Manolescu: This was certainly important for me in high school, and it helped with my career path, since it enabled me to get a scholarship to study at Harvard. I should say

that my performance involved a good amount of luck. I prepared a lot for the contests, but it is not the case that I could have solved any Olympiad problem. For example, I did not solve all the problems on the Romanian selection tests for the IMO. It just happened that I managed to see the solutions to the IMO problems, the three times that I participated.

Diaz-Lopez: *If you could recommend one book to graduate students, what would it be?*

Manolescu: *Milnor's Morse Theory* is the book that turned me towards geometry and topology. It is short, clear, and beautifully written. It not only covers Morse theory (which lies at the basis of the study of manifolds), but also touches upon several other useful topics, from the Lefschetz theorem in algebraic geometry to Bott periodicity. Chapter 2 is the place from where I first learned the basics of differential geometry.

Image Credits

Photo of Ciprian Manolescu courtesy of Reed Hutchinson.

Figure 1 based on Figure 7 of "An introduction to knot Floer homology," *Physics and Mathematics of Link Homology* 680 (2016), Amer. Math. Soc. and CRM.

Alexander
Diaz-Lopez

ABOUT THE INTERVIEWER

Alexander Diaz-Lopez, having earned his PhD at the University of Notre Dame, is now assistant professor at Villanova University. Diaz-Lopez was the first graduate student member of the *Notices* Editorial Board.

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