Research statement

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My main research interest is quantum information theory and quantum computation. I have been involved in research mostly in entanglement theory, but I'm also interested in more mathematical and combinatorial aspects of quantum information processing, including complexity theory and design of quantum algorithms. The MIT faculty members whose research is closest to my interests are Peter Shor, Seth Lloyd, Edward Fahri and Jeffrey Goldstone, though I also find work of other faculty members appealing - especially Scott Aaronson's recent paper on the interplay between complexity theory and linear optics and theoretical aspects of research by Isaac Chuang's quantum group. Topics I can imagine myself working on include, but of course are not limited to, are quantum adiabatic computation, many-body quantum computation, quantum codes, quantum channel theory.

My first serious research experience was a summer internship at the Centre of Theoretical Physics in Warsaw in 2009. I worked with prof. Marek Kuś on a problem in entanglement theory, namely, trying to find universal entanglement witnesses for distinguishable and indistinguishable particles using Lie group representation theory and generalized coherent states. We employed a geometric approach to nonclassical correlations which allowed us to put some previous results concerning entanglement measures (e.g. concurrence) in a unified framework. Specifically, we show how computable and experimentally testable entanglement meaures can be directly extracted from representations of the symmetry group of the system. The work required good understanding of both underlying physics and mathematical methods, mostly representation theory of Lie groups and algebras. Our results appeared in a paper: "Universal nonlinear entanglement witnesses", published in Physical Review A. Partly thanks to this work, I'm invited by prof. Maciej Lewenstein to the Institute of Photonic Sciences in Barcelona to conduct research in quantum information theory in the Spring of 2011.

I have also participated in a summer research fellowship at the Weizmann Institute of Science in Israel in 2010, where I conducted research with prof. Vered Rom-Kedar in the field of dynamical systems. My project consisted of analytical and numerical studies of a certain three dimensional dynamical model related to chaotic billiards (Fermi acceleration). While the work did not yield publishable results, it helped me to broaden my knowledge of dynamical systems and computational skills, including numerical modelling. During my stay in Israel, I had opportunities to interact with top experts in their fields, especially in probability and experimental quantum information (trapped ions and cold atoms).

Currently, I'm working towards my Master thesis in mathematics (supervised by Piotr

Przytycki), trying to generalize some previous results about spectral properties of random groups. As this research topic lies at the intersection of geometric group theory and probability, it has been an opportunity to use my knowledge about both geometry of groups and combinatorial techniques like discrete analysis on graphs and random graph theory.

As partly indicated by the variety of research topics described above, my academic background is fairly broad, comprising pure mathematics as well as theoretical physics and computer science. I have taken graduate-level courses in topics as diverse as logic and computation, advanced quantum mechanics or statistical physics. Thus, besides doing purely theoretical work, I can also imagine myself cooperating fruitfully with physicists. While I did not have any opportunity to do research in quantum computation, as this area is not very active in Europe, I believe my background will be sufficient to try tackling problems in this discipline. I have devoted time to self-studying selected topics in quantum computation (e.g. error correction, quantum random walks) and getting acquainted, through paper reading and conference attendance, with recent advances in the field.

Moreover, I have been also actively involved in organizational and teaching activities. As the president of Mathematics Students Society, I have coordinated and lectured at a student seminar in analysis and probability, which has covered topics including convex geometry, probability on groups and spectral graph theory. Also, for five years now, I have been coorganizing and teaching courses at nation-wide scientific workshops for gifted high school students, introducing them to university-level science.

The research experience I have obtained so far makes me confident I'm well prepared to graduate studies and, as a long-term goal, an academic career, both in terms of "hard" (problem solving, perseverance) and "soft" (organization and communication) skills. I express hope that pursuing a PhD degree at MIT would provide me with opportunities to work with top experts in quantum information and computation, develop a "big picture" view of the field, help to get introduced to new and important problems (and learn finding fruitful avenues of research myself) and fully develop my scientific potential.