ACT Adjoint School 2019 Application

Brandon Shapiro

1. Background

I covered the basic material of category theory several times, first loosely in graduate algebra and algebraic topology classes, then by reading all of Emily Riehl's Category Theory in Context over the summer before starting at Cornell, then again simultaneously in a homological algebra class mostly focused on category theory and a class on category theory for computer scientists. In the past year and a half at Cornell I've also studied topics such as operads, multicategories, model categories, monoidal/closed/enriched categories, lots of homotopy theory, all sorts of higher categorical structures, type theory and models thereof, univalence, topoi, universal algebra, and cocompletions. Also in the course of my research projects I've worked extensively with Reedy categories, monads, simplicial sets, and more general presheaf structures.

As for the project areas, I have quite a bit of experience with functional programming and immitating mutation of data structures through functional constructs in Haskell, and some limited experience with each of the others. I learned Haskell in an independent study group in undergrad, went on to use it in a summer project at Draper Laboratories, and have continued to do little exercises in it on and off since then. I also took a functional programming class at Brandeis using Scheme that went into continuation passing style and other PL ideas, and Cornell's PL class which had assignments in OCaml. While I am very familiar with monads and comfortable with bar constructions, I have only an undergrad level familiarity with probability theory. I studied physics as well in undergrad, and have a basic understanding of quantum mechanics and quantum circuits. I've taken classes on automata theory/computability, programming languages, and algorithms so I have some familiarity with complexity theory. I have some experience from various classes with reasoning about different sorts of logic and deduction systems (first order, linear, various modalities), and sat in on a graduate class in Model theory.

2. Degree Status

I am in my second year of PhD studies at Cornell in the math department, working with Inna Zakharevich. I hope to graduate in 2022 and anticipate primarily studying

higher category structures from various points of view, in particular how certain properties of a category relate to its ability to model different sorts of higher structures. I have also completed the requirements for a masters in computer science from Cornell.

3. Project Preference

Above all else, I would be excited to participate in any of the projects. Each of them covers a topic I find interesting and would love to learn more about, so I want to emphasize that I would be enthusiastic about even those lower on the following list.

1. Partial Evaluations, the Bar Construction, and Second-Order Stochastic Dominance
2. Traversal Optics and Profunctors
3. Complexity Classes, Computation, and Turing Categories
4. Toward a Mathematical Foundation for Autopoiesis
5. Formal and Experimental Methods to Reason about Dialogue and Discourse using Categorical Models of Vector Spaces
6. Simplifying Quantum Circuits Using the ZX-Calculus

Regarding my top two choices (which I have little preference between), the project on partial evaluations involves monads and simplicial structures (in the bar construction) which are central to my research interests. I am familiar with the idea of rewriting from studying logic and programming languages, which seems like a fascinating perspective on the structure of a monad or perhaps even 2-cells in 2-categories more broadly, and I would really enjoy the opportunity to study these ideas in greater depth. While I know very little about financial risk or stochastic dominance, I would love to learn more, and especially see connections with these sorts of categorical concept.

On the other hand, I originally became aware of and interested in category theory through Haskell programming, which is still something I am very interested in. For a while I struggled to reconcile how much I liked programming with my taste for abstract math, and functional programming gave me a setting for using categorical ideas to code solutions for tangible problems. I was especially awed by how in Haskell, categorical notions like monads allow us to imitate imperative programming techniques involving data mutation in a purely functional language. I know I would have a lot of fun with a project on functional

programming, and both profunctors and optics are topics I have wanted to learn more about for some time now.

4. Oxford Availability

I can definitively commit to going to Oxford if there ends up being funding available. If not, I would probably still be able to attend by putting together funding from various sources, but I won't be able to confirm this with absolute certainty until closer to the summer (though I have high confidence that it would work out).

5. Interest Statement

When I first learned category theory, I was amazed that all of my disparate interests from topology to programming to logic were suddenly related to one another. I think its fitting that over time I became more interested in those relationships than the individual topics themselves. That perspective makes me especially excited about applied category theory; it not only provides a powerful mathematical perspective to problems in other fields, but it does so in a manner specifically designed to highlight relationships between those fields and pure math. I want to be a part of that, and find ways to use the categorical ideas I know and love for broader purposes beyond mathematics. Learning about other fields from a categorical viewpoint will help me better identify how to connect my research ideas to applications, and I am particularly excited to work with researchers experienced in this sort of interdisciplinary work and other students with diverse interests and perspectives.

I also care a lot about communicating math to broader audiences, and the applied categories community has done some great expository work introducing categories in new ways that are accessible to more people. I want to be a part of that, and improve my understanding of how different backgrounds and outlooks affect how people think about categories.

I hope to have a career in mathematical research where I can study categories from all angles, and use them in new and exciting ways. This adjoint school is the perfect opportunity to meet the ACT community, get to know new ways of applying categorical ideas outside of math, and work on a research project with an interdisciplinary group, all of which helps me reach that goal. I would love to be a part of this adjoint school, and I look forward to getting more involved in applied category theory any way I can.

Brandon Shapiro

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Fields of Interest

Higher Category Theory, Combinatorial Homotopy Theory, Homotopy Type Theory

Education

2017-Future **PhD Student in Mathematics**, *Cornell Unversity*, Advisor: Inna Zakharevich..

2017-2019 **Masters in Computer Science**, *Cornell Unversity*.
Supervised by Dexter Kozen. Conferred in May 2019.

2013-2017 **Bachelor of Arts with Highest Honors in Mathematics**, *Brandeis University*.
Key Courses: Homotopy Theory, Algebra, Differential Geometry. 4.0/4.0 GPA.

2013-2017 **Bachelor of Science in Computer Science**, *Brandeis University*.
Key Courses: Modal Logic in Language, Computing Theory, Database Systems. 4.0 GPA.

2013-2017 **Bachelor of Arts in Physics**, *Brandeis University*.
Key Courses: General Relativity, Classical Mechanics, Statistical Mechanics. 3.97 GPA.

Spring 2016 **Brandeis India Science Scholars Program**, *Indian Institute of Science*.
Key Courses: Computational Topology, Mathematical Quantum Mechanics, Analysis

Honors and Awards

2017 **National Defense Science & Engineering Graduate Fellowship**
May 2017 **Summa Cum Laude**, Brandeis University
May 2017 **Arnold Shapiro Prize in Mathematics**, Brandeis University
May 2017 **Michtom Prize in Computer Science**, Brandeis University
2016 **Phi Beta Kappa**, Brandeis University Chapter, Junior Year Inductee
Aug. 2016 **Outstanding Presentation Award**, MAA MathFest 2016
2013 **Presidential Merit Scholarship**, Brandeis University
2013 **National Merit Scholarship**, Brandeis University

Papers

[1] **Densities of Hyperbolic Cusp Invariants.** *Proceedings of the American Mathematical Society*, Volume 146, Number 9, **4073-4089**, 2018. With C. Adams, R. Kaplan-Kelly, M. Moore, S. Sridhar, and J. Wakefield. [arXiv]

[2] **specgen: A Tool for Modeling Statecharts in CSP.** *Nasa Formal Methods* **282**, 2017. With C. Casinghino.

[3] **Nonstandard Neutrino Interactions In Supernovae.** *Physical Review D* **94**, 093007, 2016. With C.J. Stapleford, D.J. Väänänen, J.P. Kneller, and G.C. McLaughlin. [arXiv]

Talks

August 2018 **Cell Shapes for Higher Structures.** Young Topologists Meeting, Copenhagen.
August 2016 **The Geometry of Knots.** With S. Sridhar. MAA MathFest, Columbus, OH.
August 2016 **Cusp Density: Dense or Knot?** Unknot III, Columbus, OH.
August 2014 **Neutrinos and the Unknown** Museum of Natural Sciences, Raleigh, NC.

Workshop Participation

June 2018 **Homotopy Theory Summer**, *Berlin Mathematical School*.
Equivariant Homotopy Theory & K-Theory, ∞-Categorical A^1 Homotopy Theory

May 2018 **Talbot Workshop**, *Government Camp, OR*.
Model Independent ∞-Category Theory. Mentored by Emily Riehl, Dominic Verity.

Summer 2016 **SMALL REU**, *Williams College*.
Hyperbolic Knot Theory Group. Advised by Colin Adams

Summer 2015 **Internship Project**, *Draper Laboratories*, Formal Methods Group.
Developed and implemented in Haskell a translation model from statecharts into CSPm

2014-2015 **Astrophysics Research**, *Brandeis University*.
Analyzed plasma jets from AGN via image processing. Advised by David Roberts.

Summer 2014 **Computational Astrophysics REU**, *North Carolina State University*.
Analyzed dependence of supernova neutrino oscillations on potential non-standard particle interactions using computer simulation. Advised by James Kneller.

Employment

2018 **Teaching Assistant**, *Cornell University*, Mathematics Department.

2015-2016 **Teaching Assistant**, *Brandeis University*, Computer Science Department.

2015 **Software Engineering Intern**, *Draper Laboratories*, Formal Methods Group.

2015 **Tutor**, *Brandeis University*, Computer Science Department.

Independent Study

Fall 2018 **∞-Category Theory Reading Group**, *Cornell University*, Presenter.

Spring 2018 **Homotopy Type Theory Group**, *Cornell University*, Organizer, Presenter.

Spring 2018 **Homotopy Theory Group**, *Cornell University*, Presenter.

2016-2017 **Floer Homology Group**, *Brandeis University*.

Spring 2015 **Haskell and Type Theory Group**, *Brandeis University*.

Graduate Level Coursework

Cornell Program Logics, Set Theory, Simplicial Structures, Algorithms, Model Theory, Homological Algebra, Programming Language Theory, Kleene Algebras, Topological K-Theory, Type Theory, Hyperbolic Geometry, Algebraic Geometry.

Brandeis Homotopy Theory, Algebraic Topology (2), Algebra (2), Smooth Manifolds, Differential Geometry, Modal Logic for Computational Linguistics, Statistical Mechanics, General Relativity, Classical Mechanics.

IISc Computational Geometry & Topology, Mathematical Quantum Mechanics, Complex Analysis, Measure Theory.

Extracurricular

2016-2017 **Founder and President, Math Club**, *Brandeis University*.
Organized meetings and led newly formed math club to student union recognition.

2015-2017 **Undergraduate Mathematics Department Representative**, *Brandeis University*.
Acted as student advisor and undergaduate liaison in math department.
Organized events and programs for undergraduates in mathematics.

Gmail **Applied Category Theory <act2019school@gmail.com>**

Brandon Shapiro application

1 message

Inna Zakharevich <zakh@math.cornell.edu> Mon, Jan 28, 2019 at 12:20 PM
To: act2019school@gmail.com

Dear organizers,

I'm working to support Brandon Shapiro's application to ACT 2019.

Brandon is a second year student working with me on research connected to homotopy type theory and categorical models of homotopy types. Brandon has a strong background in category theory and homotopy theory (including model categories and alternate models for The homeroom theory of spaces). As a starting project, he has been working on a formal classification of test categories, and their connection to homotopy type theory.

Brandon's goal for his PhD is to work on homotopy type theory and univalent foundations. However, he is also very interested in connections between category theory and other fields. He would benefit from attending ACT by seeing how other people who use category and learning more about Alexis if category theory not directed towards homotopy theory.

Brandon is an excellent student and an excellent community member: he enjoys talking to people, both to learn and to explain, he always asks good questions and thinks carefully about their answers, and he is always excited about learning something new. I hope that you accept him.

Best regards,
Inna Zakharevich