HMMT February 2024 Education Events

Education Events Schedule

February 18, 2024

Time (EST)	2–105	2-131	2-132
8:00 AM–8:50 AM	**Breakfast** 4-159 (serving) and 4-163 (eating)		
9:00 AM–9:50 AM	**Marvin Li** *ChatGPT, please draw a cat: the beautiful mathematics behind diffusion models*	**Janabel Xia** *Entropic Methods in Combinatorics*	**Ophelia Sommer** *Eikonals, Matter-Waves, and the Principle of Least Action*
10:00 AM–10:50 AM	**Yufei Zhao** *Gems from the Probabilistic Method* 10-250		
11:00 AM–11:45 AM	**Lunch** 4-159 (serving) and 4-163 (eating)		
11:50 AM–12:40 PM	**Sanath Devalapurkar** *The arithmetic/geometry of quadratic forms, and elliptic curves*	**Anand Natarajan** *Quantum Algorithms: The Fourier Transform Meets the Double Slit Experiment*	**sarah-marie belcastro** *Tetris-y Tilings*
12:50 PM–1:40 PM	**Tom Hull** *Origami Logic* 10-250		

9:00 AM–9:50 AM

Marvin Li

ChatGPT, please draw a cat: the beautiful mathematics behind diffusion models

Location: 2-105

In this talk, I will present the main ideas behind denoising diffusion probabilistic models, the key technology behind text-to-image models like DALLE-3, Midjourney, and StableDiffusion. I will introduce and give a short history of the different components of a diffusion model. Then I will discuss the physical and mathematical underpinnings of the diffusion process, as well as some recent breakthroughs made in the theory of diffusion models! Finally I will describe my own research with Prof. Sitan Chen at the Harvard School of Engineering and Applied Sciences, on extending that theory to understand how (and where) diffusion models make discrete design decisions.

Marvin Li is a junior at Harvard College studying computer science and math. Outside of classes, Marvin is interested in applying mathematics to understand deep learning. In particular, Marvin has conducted theoretical and empirical research in large language models and diffusion models, which may hopefully improve the safety and efficacy of these tools.

Janabel Xia

Entropic Methods in Combinatorics

Location: 2-131

In this talk, we highlight the various applications of entropic methods to combinatorial problems. We begin by introducing Shearer's lemma, which we use throughout our combinatorial applications. We then cover two main examples. The first is the Loomis-Whitney theorem, and the second is a problem on an intersecting family of graphs first raised by Simonovits and Sós in 1976. We provide proofs for each and, in doing so, highlight the unexpected yet beautiful connections between information theory and combinatorics.

Janabel Xia is currently a senior studying mathematics at MIT. She enjoyed playing in math competitions growing up, and now plans to pursue a PhD in math/computer science next fall. Her favorite areas of mathematics include combinatorics and theoretical computer science. Outside of math, she is broadly interested in urban planning and design. She also loves to dance and choreograph, make Spotify playlists, cook with friends, and read random articles on the internet.

Ophelia Sommer

Eikonals, Matter-Waves, and the Principle of Least Action

Location: 2-132

How does the universe decide what to do? Whether it is the trajectory of a baseball, how air vibrations carry sound, or anything else in the world of classical physics, it is commonly stated that Newton's laws of motion reign supreme, but why? In this talk, we'll make a comparison between light and mechanics, and by understanding how Fermat's principle and Snell's law arise from the wave nature of light, we will gain a new perspective on mechanics. This talk will unravel the mysterious principle that the universe evolves such that it minimizes its action, and lead us to the doorstep of quantum mechanics.

Ophelia Sommer is a second year PhD student at Harvard University working with Prof Ashvin Vishwanath. Her research interests range broadly within theoretical condensed matter and quantum many body physics, with a current focus on the classification of topological phases of matter. Before her PhD she was an undergraduate at Trinity College, University of Cambridge, where she won numerous prizes, including the Hartree and Clerk Maxwell prize, the Ver Heyden de Lancey Prize, and the AC5 International Union of Pure and Applied Physics Early Career Scientist Prize.

10:00 AM–11:00 AM

Yufei Zhao

Gems from the Probabilistic Method

Location: 10-250

The probabilistic method is an influential method in combinatorics. The idea is to introduce randomness to help solve a problem, even if the problem does not initially involve any probability. I'll show a few neat examples illustrating this method. We'll see lower bounds to Ramsey numbers, as well as solutions to problems in extremal set theory.

Yufei Zhao is Associate Professor of Mathematics at MIT. His research tackles a broad range of problems in discrete mathematics, including extremal, probabilistic, and additive combinatorics, graph theory, and discrete geometry, as well as applications to computer science. His honors include the SIAM Dénes Kőnig prize (2018), the Sloan Research Fellowship (2019), and the NSF CAREER Award (2021).

11:50 PM–12:40 PM

Sanath Devalapurkar

The arithmetic/geometry of quadratic forms, and elliptic curves

Location: 2-105

"Linear" objects in mathematics are generally considered quite simple and are especially easy to study. "Quadratic" objects, however, are significantly more interesting, and turn out to contain a lot of deep mathematics. In this talk, I would like to tell you a story about quadratic equations in two variables, counting the number of integer solutions, and a relationship to quadratic reciprocity. If there is time, I'll discuss how when you try to generalize these results to elliptic curves, you'll end up with questions which remain open to this day.

Sanath Devalapurkar is a fourth-year graduate student at Harvard in the math department. He is interested in algebraic topology and its relationships to other parts of mathematics, like arithmetic geometry and representation theory. Sanath also likes playing the drums and listening to prog metal.

Anand Natarajan

Quantum Algorithms: The Fourier Transform Meets the Double-Slit Experiment

Location: 2-131

The Fourier transform has many applications throughout math and the sciences. In this talk I will present the Fourier transform for Boolean functions, and explain how it lies at the heart of the quantum algorithm for Simon's problem, the immediate precursor of Shor's famous factoring algorithm. Along the way, we'll learn the basic rules of quantum mechanics, and a little bit of linear algebra too. Only precalculus math will be assumed.

Anand Natarajan is an assistant professor in the theory of computation group in the EECS department at MIT. His research focuses on quantum computing and computational complexity theory. His education was in physics, with a PhD from MIT under Aram Harrow and a BS from Stanford.

sarah-marie belcastro

Tetris-y Tilings

Location: 2-132

You know that you can tile your kitchen floor with square tiles. But what if you're dealing with tiles that are a bunch of squares glued together... like Tetris pieces? Questions arise: Can you tile the floor with just one shape of tile? If so, can you do it in more than one way? What kinds of symmetries must the tiling have (or not have)? We will explore these issues, and you will get to experiment with making such tilings yourself and try to reason about them. In the end, we will generate more questions than answers… Believe it or not, studying these made-of-squares tiles is related to the recent discovery of the `hat' aperiodic monotile—come to this activity/talk and find out how!

sarah-marie belcastro is a free-range mathematician. She is currently Director of MathILy, Research Affiliate at Smith College, Visiting Scholar at Franklin & Marshall College, and Instructor at the Art of Problem Solving. She earned her Ph.D. from the University of Michigan and did her undergraduate work at Haverford College. sarah-marie's primary research area is topological graph theory; she is also interested in the mathematics of knitting, dance, infectious disease modeling, pharmacokinetics, and changing the world. She enjoys connecting people to each other, connecting ideas to each other, and connecting people to ideas. sarah-marie has written an introductory discrete mathematics textbook and co-edited three volumes on mathematics and fiber arts.

12:50 PM–1:40 PM

Tom Hull

Origami Logic

Location: 10-250

Over the past 20+ years, interest in origami, the art of paper folding, has been increasing as a field of study in math, computer science, physics, and engineering. One reason is because origami is complex enough to do actual computation. In this hands-on activity, participants will discover some of the basic rules of flat-foldable origami and see how they can be used to design origami-based logic gates.

Thomas Hull is an Associate Professor of Applied Mathematics at Franklin & Marshall College, where he managed to corral students who want to research the many mathematical problems that exist in origami. He has written numerous research papers on origami as well as two books: Origametry (a monograph on origami-math) and Project Origami (which describes how to use origami to teach math). He has been on the board of directors for OrigamiUSA, and one of his origami inventions (the Five Intersecting Tetrahedra model) was voted by the British Origami Society as one of the top 10 origami models of all-time.