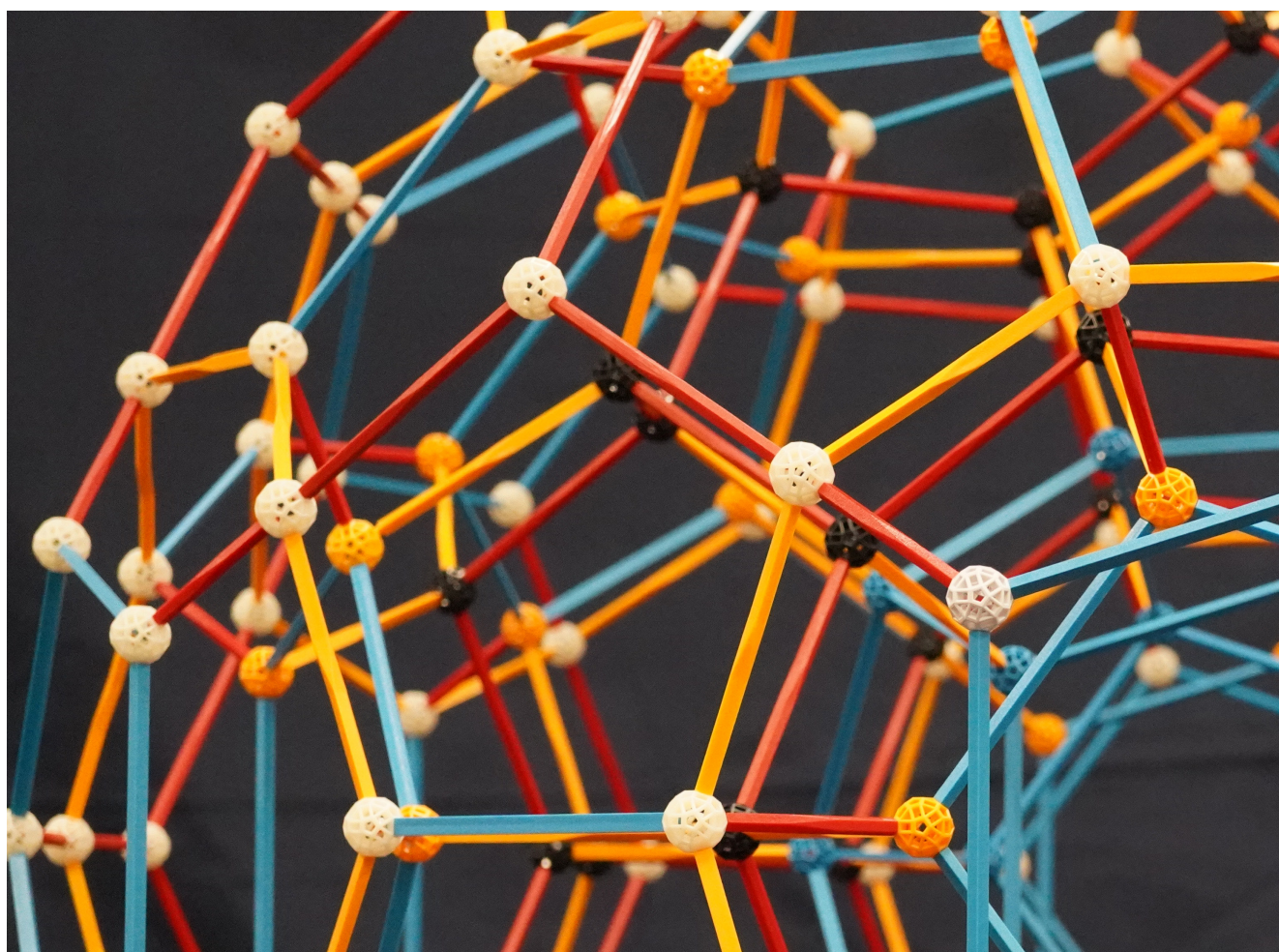


Autumn 2022

# AIMatters

Newsletter of the American Institute of Mathematics



**Fourier Restriction Conjecture** No Restrictions on this Community

**Joint Mathematics Meetings** AIM Becomes a Partner

**50 Years** Number Theory & Random Matrix Theory

**AIM Moves to Caltech** There's No Place Like a New Home

# Letter from the Director

## Hello, Pasadena!



**G**reetings (for the last time) from San Jose! AIM will move to the Caltech campus sometime around August 1, 2023. We will be located in the (soon-to-be) newly created Richard N. Merkin Center for Pure and Applied Mathematics on the 8th floor of Caltech Hall. We are absolutely delighted to be starting this partnership with such a prestigious and welcoming institution!

While we are excited about our move, we do wish to thank Fry's Electronics for their loyal and continuing support throughout the years and especially for providing space for AIM since its beginning, first in Palo Alto, and then in San Jose.

We returned to in-person workshops and SQuaREs this year. In fact we will have 18 in-person workshops and 61 in-person SQuaREs by the end of the year. We have lectures and working groups meeting as before, but lunch is served outside in a very nice new picnic area. After lunch, participants can take a break from the math and play a variety of games, including rounds of pickleball on a court created in the parking lot. It's great to see everyone again as the world struggles to start back up.

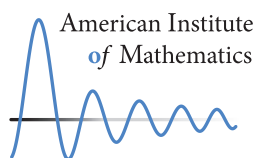
We have many new Scientific and Human Resources Board members. You can view a list of all new members in this issue. We look forward to an active season of selecting new workshops, SQuaREs and AIM Research Communities to run in the next academic year. One of our newer Scientific Board members, Melanie Machette Wood, was recently named a 2022 MacArthur Fellow. She has been associated with AIM since 2009 when she was named an AIM Five Year Fellow. Congratulations to Melanie!

I am sorry to say that long-time Scientific Board member Georgia Benkhart died this year. She is greatly missed by the mathematics community.

AIM became an official partner of the AMS and will have quite a few activities at the Joint Mathematics Meetings (JMM) in Boston this coming January. For one thing we will be presenting the fourth Alexanderson Award as part of the Joint Prize Session on Thursday, January 5, 2023. The awardees this year are Jan Bruinier, Benjamin Howard, Stephen S. Kudla, Michael Rapoport, and Tonghai Yang. Their magnificent work on the modularity of generating series of divisors on unitary Shimura varieties comprises 186 pages of *Astérisque*, published by the Société Mathématique de France, volume 421. In addition AIM will be sponsoring special sessions on Little School Dynamics ("Cool Dynamics Research by Researchers at PUIs") and another on Automorphic Forms and Special Cycles.

Our new K-12 initiative, Math Communities, program is off to a good start. You can read all about it, our move, JMM, and more in this issue. Enjoy! ■

*Brian Conrey*



**American Institute of Mathematics**  
600 East Brokaw Road  
San Jose, CA 95112  
Phone: (669) 333-7600  
<https://aimath.org>

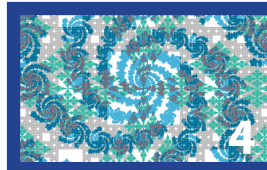
### AIMatters

**Editor-in-Chief:** J. Brian Conrey

**Art Director:** Sally Morrison

**Contributors/Editors:** Kelley Barnes, Estelle Basor, Brian Conrey, Brianna Donaldson, Leslie Hogben, Stephen S. Kudla, Michelle Manes

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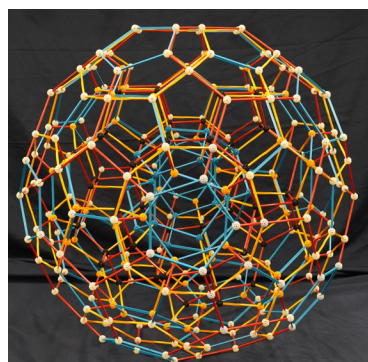
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## ABOUT THE COVER IMAGE

On the cover is a Zometool construction of a three-dimensional projection of a four-dimensional regular polytope known as the 120-cell, dodecaplex, or hyperdodecahedron.

Benoit Charbonneau from the University of Waterloo led some participants of the workshop in building this object at the AIM workshop, Geometry and physics of ALX metrics in gauge theory, held in July of 2022.



# Fourier Restriction Conjecture

## No Restrictions on this New Research Community

As in-person workshops and SQuaREs finally return, AIM continues to support virtual collaboration efforts through AIM Research Communities. These Communities are larger than Workshops (at least 40 participants and often many more) and have a longer time frame (a year or more).

In March, 2022 one of the newest Research Communities, focused on the Fourier restriction conjecture and related problems, launched with a talk by Prof. Larry Guth from MIT “about some open problems and about the obstacles that seem to be making the problems difficult.” Several dozen participants attended the virtual lecture, and more than 20 people stayed on for a virtual office hour following the talk.

The new Research Community is organized by Dominique Maldague (MIT), Yumeng Ou (University of Pennsylvania), Po-Lam Yung (Australian National University), and Ruixiang Zhang (UC Berkeley). The goal of the research community is to bring together mathematicians who are studying the Fourier restriction conjecture, which predicts that if  $S$  is a curved smooth submanifold of Euclidean space, then taking the Fourier transform and restricting to  $S$  extends to a bounded linear operator (from  $L^p(\mathbb{R}^n)$  to  $L^1(S)$  for certain  $p$ ). The organizers explain that the behavior is unexpected since the Fourier transform of an  $L^p$  function is *a priori* only almost everywhere defined, and  $S$  is a zero measure set in  $(\mathbb{R}^n)$ . This conjecture is deep and far-reaching and has surprising connections to PDE, number theory, incidence geometry, combinatorics and geometric measure theory.

AIM Research Communities are tailored to the particular needs of the group. The organizers of the Fourier Restriction Conjecture Research Community hope to introduce early career mathematicians to the field and to facilitate collaborations within the field. To that end, they are organizing a variety of activities.

- **Reading groups for graduate students and postdocs:** About eight reading groups, each with about five participants, are currently active in the community. Each group selected a paper to study together.
- **Problem session:** A live (but virtual) problem session was held at the end of March, modeled on the problem sessions run at AIM workshops. Participants generated a list of 10 open problems in the area. Descriptions of the problems were later distributed to the whole community and working groups have been formed for each problem.
- **Research groups:** Small research groups have formed to tackle the open problems, and group meetings were organized for each group over the summer.

Find out more about this Research Community on their AIM webpage (<https://aimath.org/programs/researchcommunities/fourierrestriction/>) or their YouTube Channel HAPPY (<https://web.sas.upenn.edu/harmonic-analysis/>). ■

– Michelle Manes

## CALL FOR PROPOSALS

AIM is accepting proposals for three types of research activities:

- **Weeklong AIM-style Workshops** for 28 people. Workshops can either be in person or online, with separate proposal forms for each format.
- **SQuaREs** for 4-6 people, who meet in-person for a week, with the possibility of returning for two additional meetings in subsequent years.
- **AIM Research Communities (ARCs)**, which are larger groups who meet online over an extended period of time.

For more details and online applications: [www.aimath.org](http://www.aimath.org)

# Joint Mathematics Meetings

## AIM Becomes a JMM Partner

AIM has always had a big presence at Joint Mathematics Meetings, and we're excited to build on that by becoming an official JMM partner beginning with the 2023 JMM in Boston. We're particularly looking forward to bringing the Alexanderson Award and Lecture to the JMM, allowing the broader mathematics community to celebrate the excellent research that comes out of AIM workshops and SQuaREs. The award will be given during the JMM Prize Ceremony, and the 2023 Alexanderson Award Lecture will be delivered by Dr. Stephen Kudla.

Each year, AIM will sponsor Special Sessions tied to AIM activities (workshops, SQuaREs, Research Communities, and Special Programs). In 2023, look for these AIM-Sponsored Special Sessions while you're at JMM:

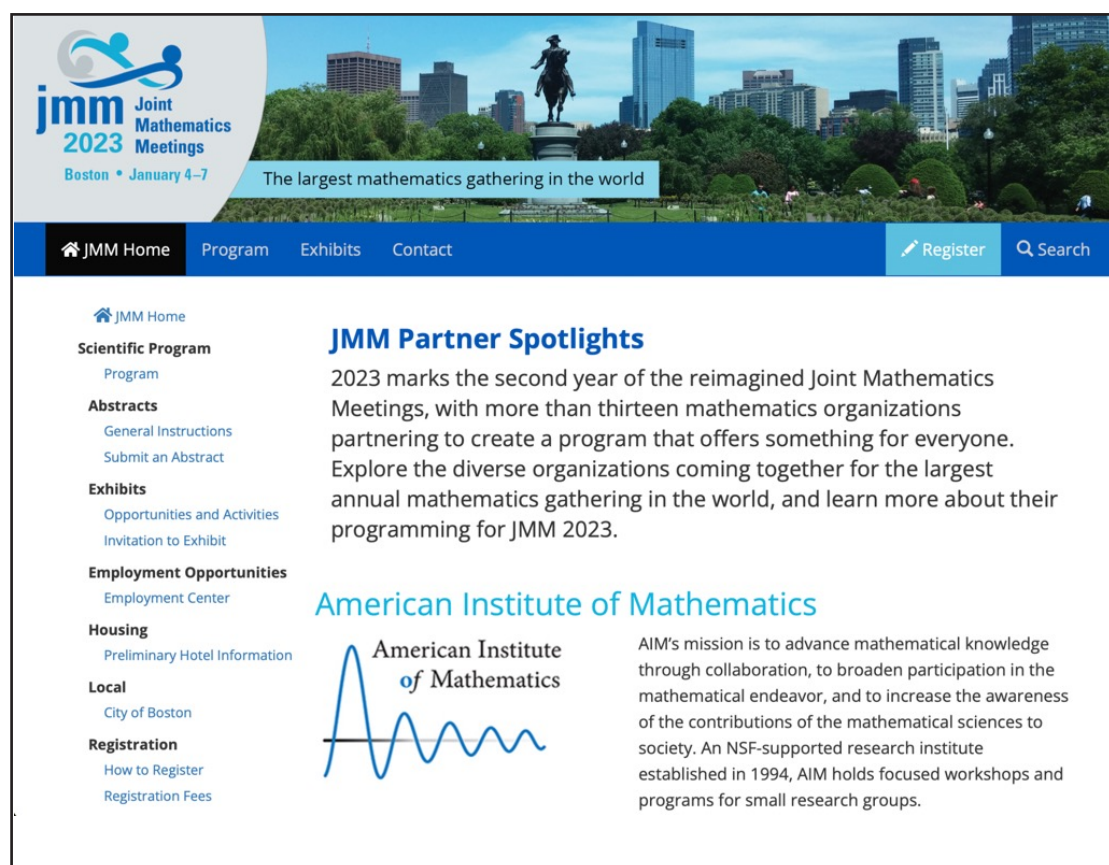
- **Little School Dynamics: Cool Dynamics Research by Researchers at PUIs.** This special session is co-organized by Kimberly Ayers, Ami Radunskaya, Han Li, David McClendon, and Andrew Parrish; it's affiliated with the Little School Dynamics Research Community (<https://aimath.org/programs/researchcommunities/dynamics/>).
- **Automorphic Forms and Special Cycles.** This special session is co-organized by Stephen Kudla, Jan Hendrik Bruinier, and Tonghai Yang; it's affiliated with an ongoing AIM SQuaRE on "Arithmetic theta series of genus 2" and is co-organized by this year's winners of the Alexanderson Award.

AIM will also sponsor Professional Enhancement Programs (PEPs) at each JMM. These hands-on professional development opportunities will vary from year to year. Consider adding one of these PEPs to your 2023 JMM schedule:

- Creating accessible and interactive documents with PreTeXt.
- How to Run Successful Math Circles for Students and Teachers.

We hope everyone will stop by the AIM booth to learn about all of our other activities, and please join us at the Math Circles Reception! ■

– Michelle Manes



The screenshot shows the JMM 2023 website. The header features the JMM logo and the text "Joint Mathematics Meetings 2023 Boston • January 4–7". Below the header is a navigation bar with links: JMM Home, Program, Exhibits, Contact, Register, and Search. The main content area is divided into two columns. The left column contains a sidebar with links to various sections: Scientific Program, Abstracts, Exhibits, Employment Opportunities, Housing, Local, and Registration. The right column features a "JMM Partner Spotlights" section with a paragraph about the 2023 event, followed by a section for the "American Institute of Mathematics" with a logo and a paragraph about its mission.

**JMM 2023** Joint Mathematics Meetings  
Boston • January 4–7  
The largest mathematics gathering in the world

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**JMM Partner Spotlights**  
2023 marks the second year of the reimagined Joint Mathematics Meetings, with more than thirteen mathematics organizations partnering to create a program that offers something for everyone. Explore the diverse organizations coming together for the largest annual mathematics gathering in the world, and learn more about their programming for JMM 2023.

**American Institute of Mathematics**  
AIM's mission is to advance mathematical knowledge through collaboration, to broaden participation in the mathematical endeavor, and to increase the awareness of the contributions of the mathematical sciences to society. An NSF-supported research institute established in 1994, AIM holds focused workshops and programs for small research groups.

# The 2022 Alexanderson Award

## Modularity of Generating Series

The recipients of the fourth Alexanderson Award are Jan Bruinier, Benjamin Howard, Stephen S. Kudla, Michael Rapoport, and Tonghai Yang for their paper “Modularity of generating series of divisors on unitary Shimura varieties” published in two parts as a monograph in 2020 in *Astérisque*, (421).

The formation of generating series is a longstanding technique in many areas of mathematics.

Typically, some ordered sequence of numbers is given and the generating series is obtained by taking these quantities as the coefficient of  $q^n$  in a power series in a parameter  $q$ . For example, if the  $k$ th term in the sequence is the binomial coefficient  $\binom{n}{k}$ , then the series is the familiar

$$\sum_{k=0}^n \binom{n}{k} q^k = (1+q)^n.$$

If the sequence consists simply of ones, then the answer is

$$\sum_{k=0}^{\infty} q^k = \frac{1}{1-q}.$$

Notice that in both these cases, the series collapses to a rational function of  $q$ .

In general, the resulting power series is just a formal object with no analytic meaning. But it can happen

that the generating series has a power series expansion that has some special properties related to the theory of modular forms. A modular form is a function defined on the upper half of the complex plane with some remarkable symmetry properties.

To be more precise, a function  $f$  is modular when it is analytic in the upper half plane ( $\Im(z) > 0$ ), bounded as  $z$  tends to infinity on the imaginary axis, and satisfies for all  $a, b, c, d \in \mathbb{Z}$ , such that  $ad - bc = 1$

$$f\left(\frac{az+b}{cz+d}\right) = (cz+d)^k f(z)$$

for some  $k$ , usually a positive integer, and all  $z$  in the upper half plane.

When the generating function coincides with the expansion at infinity of a modular form, the generating series is said to be modular. The main breakthrough of the AIM SQuaRE project was a proof of the modularity of the generating series for some special classes of sequences and resulting in important links between arithmetic geometry and analysis.

For the interested reader, here are more examples and a more technical description of what was done. A noteworthy class of examples of modular generating series is the theta series that arises when the defining sequence  $a(n)$  is the number of vectors of square length  $2n$  in an even lattice in Euclidean space. For such series modularity is a consequence of the Poisson summation formula. Since the relevant space of modular forms is known to be finite dimensional, such modularity reflects a very strong coherence among the  $a(n)$ s and sometimes results in striking identities.

For the root lattice of type  $E_8$ , the relevant space of modular forms has dimension 1 and also contains the Eisenstein series of weight 4, an explicitly constructed modular form occurring in the theory of elliptic curves. This Eisenstein series can be viewed as the generating series for the numbers  $c(n)$  given by 240 times the sum of the cubes of the positive divisors of

The Alexanderson Award recognizes an outstanding scholarly article arising from research activities sponsored by the American Institute of Mathematics and published within the past three years.

The award was established in 2018 to honor the contributions of Gerald Alexanderson, Professor of Mathematics at Santa Clara University and founding chair of AIM's Board of Trustees. As its first chair, Jerry provided the stewardship that has distinguished AIM as an international center for mathematical research with a commitment to productive and creative collaboration.





$n$ , with a suitable term  $c(0) = 1$  added. It follows that this Eisenstein series coincides with the  $E_8$  theta series, proving a striking formula for the number of square length  $2n$  vectors in  $E_8$ .

Generating series can also be formed from quantities arising in geometry and in arithmetic geometry, in particular from special cycles in unitary Shimura varieties. Such varieties are constructed as quotients of the complex unit ball of dimension  $m$  by arithmetic groups coming from Hermitian lattices of signature  $(m, 1)$  over integer rings of imaginary quadratic fields. A rich supply of divisors – special divisors – is provided by the images of sub-balls of dimension  $m-1$  that are compatible with the arithmetic group action. These compatible sub-balls are associated to positive lattice vectors so that one can define special divisors  $Z(n)$  for positive integers  $n$  by collecting lattice vectors of square norm  $2n$ . Generating series are then constructed by taking the classes of the  $Z(n)$  in suitable cohomology groups. Such cohomology valued generating series can be viewed as analogues of theta series. More generally, one can construct integral models of these unitary Shimura varieties as moduli spaces of abelian schemes with an action of the imaginary quadratic integer ring. The special divisors extend to arithmetic special divisors on such models, defined in terms of moduli. Now in the formation of generating series the cohomology groups are replaced by Chow groups and arithmetic Chow groups.

The main focus of the AIM SQuaRE project was a proof of the modularity of the generating series for the classes of arithmetic special divisors in the Chow group of a compactified integral model of a unitary Shimura variety. An analogous modularity result is also proved for the classes of special divisors equipped with suitable Green functions in the Gillet-Soulé arithmetic Chow groups. In both cases, the modular generating series should be viewed as a new type of arithmetic theta series. These series are expected to have many applications as they provide a bridge between the delicate arithmetic geometry of integral models of unitary Shimura varieties and the powerful analytic machinery of modular forms. For example, they have already been used to prove Gross-Zagier style formulas relating derivatives of L-functions to arithmetic intersection pairing on unitary Shimura varieties and special cases of the Colmez conjecture on the Faltings heights of abelian varieties with complex

multiplication. More recently the modularity of the Gillet-Soulé Chow group valued series has been used by Wei Zhang to prove his arithmetic fundamental lemma relating intersections of cycles on Rapoport-Zink space to derivatives of orbital integrals. The problem of finding higher codimensional generalizations is an active area of current research. ■

– Stephen S. Kudla

### Alexanderson Award Lecture

“Modularity of generating series of divisors on unitary Shimura varieties”

January 6, 2023

2023 Joint Mathematics Meetings, Boston

Awardees:

Jan Bruinier, Ben Howard, Stephen Kudla,  
Michael Rapoport, Tonghai Yang  
Delivered by Stephen Kudla

Unitary Shimura varieties are associated to hermitian vector spaces  $V$  of signature  $(n-1, 1)$  over an imaginary quadratic field  $k$ . The complex points  $S$  of such varieties are described as quotients of the unit ball in  $\mathbb{C}^{n-1}$  by arithmetic groups  $\Gamma$  in the isometry group  $U(V)$ . Special divisors arise as the images of ‘rational’ sub-balls of dimension  $n-2$ . It has been known for a long time that the generating series for the cohomology classes in  $H^2(S)$  of certain collections of such divisors, a formal power series in a parameter  $q$ , is the  $q$ -expansion of a modular form of weight  $n$  valued in  $H^2(S)$ . These unitary Shimura varieties have (compactified) integral models  $S^*$  over the ring of integers  $O_k$  of  $k$  and the special divisors can be extended to these models. Equipped with suitable Green functions, the integral special divisors define classes in the arithmetic Chow group  $\text{Ch}_{\mathbb{Q}}^1(S^*)$ . Our main result is a proof of the modularity of the resulting arithmetic Chow group valued generating series. The lecture will describe this construction in more detail and explain some of the techniques involved in the proof. If time permits, some consequences of modularity will be mentioned.

# Launching Math Communities

## A New K-12 Initiative

Over the past decade or so, there has been tremendous growth in the number of high-quality programs focused on engaging students, teachers, and families in joyful, collaborative math experiences. However, access to these programs has been limited and has often not included underserved communities. To help broaden participation in joyful mathematics, AIM has launched a new K-12 initiative, Math Communities ([MathCommunities.org](https://mathcommunities.org)). Math Communities is intended as a one-stop shop for anyone seeking ways to bring engaging mathematical experiences to their local community. The program offers free consulting services to match individuals or organizations who serve K-12 students, families, and teachers with free or low-cost programs that meet their specific interests and needs.

For example, mathematicians visiting AIM are often interested in getting involved in K-12 outreach, but might not know where to start. Similarly, school district math coordinators might be looking for ways to increase engagement among students or ideas for getting families more involved. Teachers might want math enrichment resources for their classrooms, while parents could be looking for opportunities for their own children or ways to help out at their child's school. By consulting with Math Communities, after an initial

conversation of a half-hour to an hour, we are able to generate a tailored list of recommended resources and can also facilitate introductions to programs of interest. Our website also serves as an easy-to-use portal for finding stand-alone resources intended for different audiences. In addition, we maintain a calendar of

events hosted by partner programs, and hope to offer our own webinars and workshops in the near future.

Math Communities and our partners are especially focused on increasing access to joyful mathematics for communities that have been historically underserved mathematically, including individuals who identify as Black, Latinx, and/or Indigenous; girls, women,

and gender nonconforming individuals; individuals experiencing poverty; and individuals living in rural areas. Our current partner programs include all of AIM's K-12 initiatives (the Math Circle Network, the Global Math Project, Math Monday, Math MATCH, and the Alliance of Indigenous Math Circles) as well as several other organizations: Art of Problem Solving, Early Family Math, Julia Robinson Mathematics Festival, MathHappens, Mathigon, Math for Love, and Natural Math. We look forward to expanding our list of partners this year and to matching many additional communities with engaging mathematics programs. ■

—Brianna Donaldson

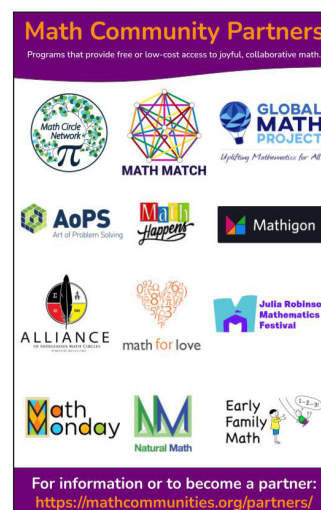


**MathCommunities.org**  
Matching schools, higher education institutions, and community organizations who serve PreK-12 students, families, and teachers with joyful, collaborative activities designed by professional mathematicians and educators.

**How can we help?**  
We offer free consultations to schools, higher education institutions, and other groups who want to bring joyful math to their communities.

<b>PreK-12 Schools &amp; Teachers</b> Math-centered events for schools and engaging, hands-on math activities & lessons for the classroom	<b>Higher Education</b> Opportunities for broader impact and means to connect with communities through joyful mathematics
<b>Community/Non-Profit</b> Math-centered events for schools and engaging, hands-on math activities & lessons for the classroom	<b>Families &amp; Students</b> Materials and games for students to play with joyful math at home or to engage with math as a family

Schedule a free consultation with us at [www.mathcommunities.org/contact](https://www.mathcommunities.org/contact)



**Math Community Partners**  
Programs that provide free or low-cost access to joyful, collaborative math.

Math Circle Network $\pi$	MATH MATCH	GLOBAL MATH PROJECT Uplifting Mathematics for All
AoPS Art of Problem Solving	Math Happens	Mathigon
ALLIANCE of Indigenous Math Circles	math for love	Julia Robinson Mathematics Festival
Math Monday	Natural Math	Early Family Math

For information or to become a partner: <https://mathcommunities.org/partners/>





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Please find us at JMM 2023 in Boston.  
Visit the AIM booth in the exhibits hall  
and join us for the  
Mathematical Institutes Open House on  
Thursday, January 5th from 6:00-8:30 PM.

# Morgan Hill Math

## 2022 Dispatches

**M**organ Hill Math is an outreach program sponsored by the American Institute of Mathematics (AIM) that provides free math enrichment activities to about 300 students each year, who live in or near Morgan Hill, CA.

Most families are introduced to Morgan Hill Math through Mathletics and MathCounts6. Happily, these two programs were reinstated after taking a year off due to the pandemic. Last fall, our youngest students, fourth and fifth graders enrolled in our eight-week Mathletics program, enjoyed lessons which included learning to play Sudoku, KenKen, and Chocolate Fix; discovering pi; exploring angles, areas, and perimeters; and practicing problem-solving strategies such as working backwards and making charts. Students in MathCounts6 were introduced to more advanced problem-solving concepts, including counting in other bases, problem posing, proportions, permutations and combinations; all skills that are necessary for successfully competing in math competitions.

*“Programs like this are why I’m majoring in Math. It made math fun, [and] a lot of kids never have fun in math,”* said a former Morgan Hill Math student, who is now at CSUMB majoring in Statistics and planning to become an actuary.

The cornerstone of the Morgan Hill Math program has always been training for and competing in MATHCOUNTS. Throughout the fall, I held weekly MATHCOUNTS training classes at four local middle schools and offered a weekly Zoom session for all other interested students. Over 70 students, from seven local schools, sharpened their skills in counting,

statistics, proportions, probability, permutations and combinations, functions, algebra, and geometry. Due to pandemic uncertainty, national plans were made for both in-person and online competitions. With the support of our student’s families and Oakwood School, our Coyote Valley MATHCOUNTS Chapter was one of only three California chapters to hold an in-person Chapter Competition! Forty students attended this event, and were so happy to be competing in person again! However, in the interest of fairness to all chapters across the country, the MATHCOUNTS foundation required us to call this a “Bonus Competition,”

and instead held an official online competition over the AoPS platform. Arrangements were made at the various schools so that students could take the contest together, in a classroom, over their own computers. So much better than the year before when they competed while isolating at home! Six students qualified for the California

State Competition. Once again we made arrangements so these students could compete together in a classroom, on their computers.

*“Over the course of two years at MATHCOUNTS, I have learned math, but I have also gained confidence. I used to believe that I was ‘bad’ at math, [but] now I realize that nobody is bad at math. Your ability to answer and solve problems that relate to math is a measure of your diligence,”* stated a current GECA student.

All interested students from Morgan Hill Math programs, 8th grade and below, were invited to participate in one or both divisions of the Math Olympiad for Elementary and Middle School (MOEMS). Over



Math Olympiad Winners 2021-2022 season

100 kids were challenged to strengthen their problem-solving skills in this once-a-month, five-question test. I held the contest over Zoom, which allowed more kids to participate. Last year's contests were particularly difficult! In the Middle School Division, eighth-grader Aditya Shirgur achieved a perfect score (25), one of only 141 students worldwide (0.9%). Ishan Mysore (8th grade) scored 24, representing 1.2% of participants; and Anna Conca (6th grade) scored 24 in the Elementary School Division, one of 0.5% of the students who participated worldwide.

*"All of our boys enjoy it, but most especially H. Thank you for challenging him and helping him learn to love math,"* said parents of Morgan Hill Math students.

Our Middle School and High School Mathletes participated in several other competitions this year. Over 50 students involved in the weekly MATHCOUNTS training classes, as well as interested sixth graders, took the AMC8, an MAA competition for students in eighth grade and below. Seventh-grader Andrew Zhang scored in the top 5%, nationwide, earning him a spot on the Honor Roll. High school students were invited to take the AMC10 or AMC12 exams. By scoring high enough, two local students, Neil Shah (12th grade) and Ethan Fang (11th grade) qualified to take the AIME, the American Invitational Mathematics Exam, which is the first in a series of examinations that culminate with the International Mathematical Olympiad (IMO). Neil received the Certificate of Distinction for scoring in the top 5%, nationwide, on the AMC12.

*"I have three kids, two boys and a girl, who have been involved in Morgan Hill Math programs from elementary school through high school. Their experiences have been wonderful and educational.*

*They appreciate the challenges provided by the problems, and the mentorship given by the programs teaches them that with practice and perseverance the problems are doable and not impossible. It has increased their problem solving skills and fostered their interest in math and technology,"* described a parent of former and current Morgan Hill Math participants.

The Morgan Hill Student Math Circle for Elementary and Middle School students continued throughout the year. We met every Monday over Zoom to explore fun math activities. Most activities were found on the Math Communities and JRMF webpages.

Making connections with students and families is what makes Morgan Hill Math so rewarding. Watching that spark light up in a student's eyes when they understand a new idea, and seeing them gain confidence and enjoyment in problem solving, there is just nothing like it for a teacher. Hearing from them what a difference I have made in their journey is amazing.

*"Thank you for providing encouragement and support in MATHCOUNTS and MOEMS! You have made math extremely engaging for me and have been an incredible coach. I will miss you! Go math!"* exclaimed an eighth grader moving onto high school. ■

– Kelley Barnes



Coyote Valley Chapter Competitors from the Bonus Competition, February, 2022



# REUF

## Returns in Person

Following a two-year pandemic gap, the Research Experiences for Undergraduate Faculty (REUF) program returned to AIM for a workshop August 1-5, 2022.

REUF, which is a collaboration of AIM and ICERM, enhances the ability of faculty at undergraduate colleges and universities to engage their students in research and allows faculty participants to develop long-term research collaborations as well as expertise in new research areas that have problems accessible to undergraduates.

Opportunities for faculty at primarily undergraduate institutions to collaborate in person can be rare. Thus, the decision was made in both 2020 and 2021 to conserve program funding and wait until we could safely hold an in-person workshop, rather than holding virtual programs in the meantime.



REUF participants enjoy the in-person interactions, both inside (top) and out (below right).

This year's workshop (which was held with COVID safety protocols, such as eating lunch and holding Happy Hour outside) had 14 participants working in three research groups:

- Generalized Symmetric Spaces, led by Loek Helminck of the University of Hawai'i at Manoa
- Incorporating Vaccination into Epidemiology Models, led by Glenn Ledder, of the University of Nebraska Lincoln
- Determinants of Skew-Adjacency Matrices of Tournaments, led by Bryan Shader of the University of Wyoming.

The workshop was a great success, and being able to meet in person was appreciated by everyone involved. We hope to resume in-person REUF alumni gatherings at the Joint Mathematics Meetings in 2023 and to hold a larger REUF workshop next summer at ICERM. ■

– Leslie Hogben

### What Participants Had to Say . . .

*"Thank you very much for giving me the opportunity to join. This was the best workshop. I have been feeling isolated and had a lost feeling, but this was a wonderful opportunity to reboot myself. I got motivated and truly learned a lot from everyone. Thank you so much for organizing such a great workshop."*

*"The workshop was really amazing. I am very grateful to AIM for making this happen. All staff members were great and I appreciate all of their efforts."*

*"I enjoyed getting to know other mathematicians (particularly those who may have higher teaching loads like me) and having the intensive time to collaborate. Having problems that were reasonably accessible without previous experience can be difficult to find."*

*"One of the most valuable parts of the program was having an experienced mentor in the area of research that we were exploring. It was incredibly validating to hear from an expert in the field that our project was promising and to provide guidance on our work. I also appreciate the community of participants here. Everyone I've met has been very helpful and open to discussing challenges that many of us have faced."*

*"I've had such a wonderful time. This was such a valuable experience for me and one that I will never forget."*



# 50 Years

## Number Theory & Random Matrix Theory

A great event occurred 50 years ago. On April 6, 1972, a young graduate student named Hugh Montgomery and the world-renowned mathematical physicist Freeman Dyson had a conversation in the tearoom at the Institute for Advanced Study, which led to a fusion of two disparate fields and an intellectual revolution that is stronger than ever today. Montgomery and Dyson discovered that the zeros of the Riemann zeta-function, important for understanding prime numbers, seem to obey the same distribution patterns as the eigenvalues of large random unitary

(or hermitian) matrices, which had been extensively studied by physicists, especially to model the interactions within large atomic nuclei. This stunning connection has held up to extensive numerical and theoretical tests

over the intervening years and has been extended to give random matrix models for the low lying zeros of families of L-functions and for the moments and distribution of values of the L-functions in these families and to analogous families over function fields. AIM decided to organize a conference commemorating this singular event and looking to the future.

AIM has a history of fostering work at the interface between Number Theory and Random Matrix Theory. One of the very first events that AIM hosted was a conference in Seattle in August 1996 entitled

“In Celebration of the Centenary of the Proof of the Prime Number Theorem: A Symposium on the Riemann Hypothesis.” This conference featured much discussion of Montgomery's pair correlation conjecture. But it also featured one of the first-ever talks by Peter Sarnak on statistics of zeros of families of L-functions and their connection to Random Matrix Theory. Furthermore, it was the starting point for the pioneering work of Jon Keating and Nina Snaith on the connection between moments of the Riemann zeta-function and moments of characteristic polynomials

of Random Matrices.

Since then AIM has co-funded four more events on the Riemann Hypothesis: in Vienna in 1998; in New York in 2002; in Bristol in 2018; and the 50 years conference at the Institute

for Advanced

study this past June. This conference, sponsored by NSF, AIM, the Heilbronn Institute, and the Institute for Advanced Study, had 130 people in attendance, alongside a virtual audience, to listen to 15 talks, including historical talks by Hugh Montgomery, Peter Sarnak, and Jon Keating. All of the talks were recorded and can be viewed from links on the website [ias.edu/math/events/50yntmrt](https://ias.edu/math/events/50yntmrt). All of the talks from the 1996 and 2018 conferences can be accessed via [aimath.org/videos/](https://aimath.org/videos/). ■

– Brian Conrey



Freeman Dyson, top, and Hugh Montgomery

# AIM Moves to Caltech

## There's No Place Like a New Home

**A**fter more than two decades in the Bay Area, AIM will move to its new home in Pasadena, CA. AIM will be located on the Caltech campus in the new Richard Merkin Center for Pure and Applied Mathematics, a research center and conference space that has been established in connection with AIM's move to Caltech, with support from Richard N. Merkin and the Merkin Family Foundation. The new center occupies the eighth floor of Caltech Hall.

The new space at Caltech will provide lecture space for workshops and breakout rooms for both workshops and small research groups in the AIM SQuaRE program as well as a reception area and office space for staff. AIM will continue regular operations at its current facility in San Jose until the move in the first half of 2023.

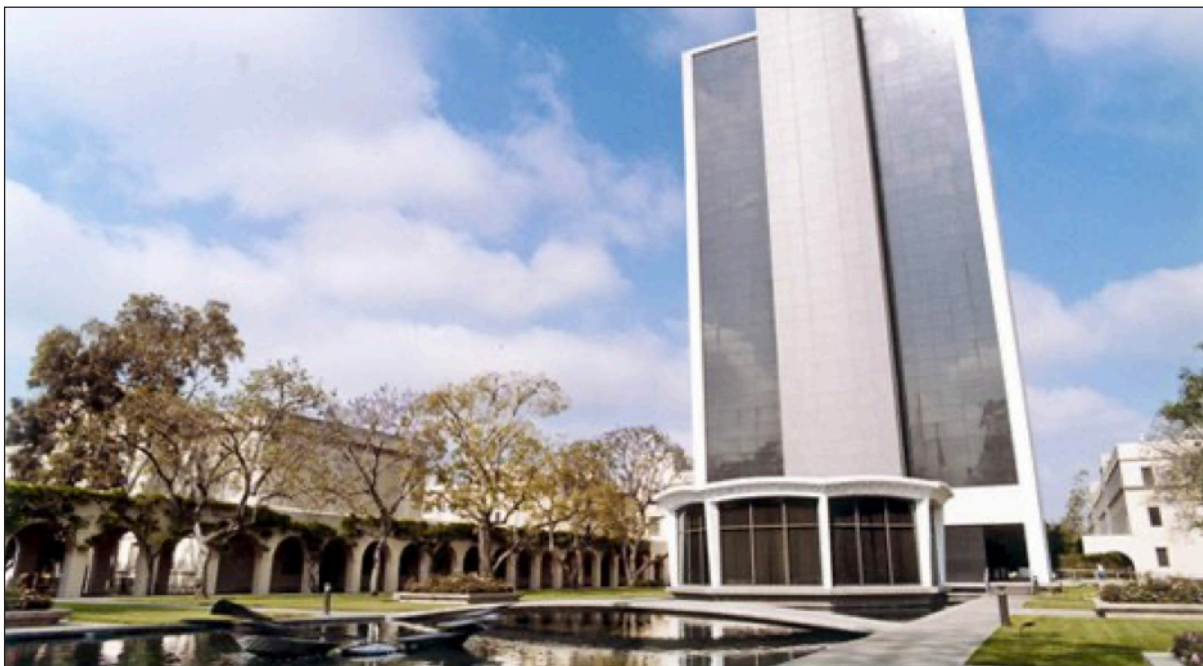
The innovations in collaborative research that began at AIM more than 20 years ago have now become part of the culture of mathematics and are a particularly good fit for Caltech, where interdisciplinary research is highly valued. Relocating at Caltech benefits both the campus and AIM. Caltech will benefit from the large number of visiting mathematicians and scientists that come to AIM each year, while AIM will benefit from

the small, energetic, focused, and interdisciplinary communities of Caltech.

Over 40 Caltech faculty have participated in AIM programs in the past. One of those, the John D. MacArthur Professor of Theoretical Physics and Mathematics, Sergei Gukov, has participated in several AIM programs and served on its scientific research board for many years. Gukov credits his own experiences at AIM with seeding some of his most influential work in the field of knot theory and its connections to a branch of algebra called representation theory. He says, "In general, AIM helps mathematicians and researchers make connections with other researchers—and new connections in their own mathematical work—to create something unexpected."

AIM is also well recognized for its educational outreach efforts and programs to support K–12 students and teachers. At Caltech, AIM will continue to grow its national outreach programs while also collaborating with Caltech's Center for Teaching, Learning, and Outreach and with local educational partners to "support joyful and meaningful math education in the L.A. area," says Brianna Donaldson, AIM's director of special projects. ■

– Estelle Basor



Caltech Hall. AIM will be located on the eighth floor.



# New Board Members

## Scientific Research and Human Resources

AIM welcomes the following new members to its **Human Resources Board**.

**2019**

**Eleanor Jenkins**, Clemson University  
Mathematical modeling, optimization, numerical analysis

**2021**

**Debra Borkovitz**, Boston University  
Mathematics education  
**Torina Lewis**, American Mathematical Society and Clark Atlanta University  
Combinatorics  
**Robin Wilson**, California State Polytechnic University, Pomona  
Low dimensional topology and mathematics education

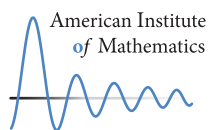
AIM welcomes the following new members to its **Scientific Research Board**.

**2021**

<b>Peter J. Bickel</b> , University of California, Berkeley Statistics	<b>Joseph Teran</b> , University of California, Davis Computational methods for partial differential equations
<b>Antonio Montalbán</b> , University of California, Berkeley Mathematical logic and computability theory	<b>Melanie Matchett Wood</b> , Harvard University Number theory and arithmetic geometry
<b>Lenhard Ng</b> , Duke University Symplectic geometry	

**2022**

<b>Rina Barber</b> , University of Chicago Statistics	<b>Raphael Rouquier</b> , UCLA Representation theory
<b>Roya Beheshti</b> , Washington University Algebraic geometry	<b>Clayton Scott</b> , University of Michigan Machine learning theory and algorithms
<b>Sourav Chatterjee</b> , Stanford University Mathematical statistics and probability	<b>Anne Shiu</b> , Texas A&M University Computational biology
<b>Ryan Hynd</b> , University of Pennsylvania Partial differential equations	<b>Mary Lou Zeeman</b> , Bowdoin College Dynamical systems and mathematical biology
<b>Svetlana Jitomirskaya</b> , University of California, Irvine Dynamical systems and mathematical physics	



American Institute  
of Mathematics  
600 East Brokaw Road  
San Jose, CA 95112

# *From Our Collections*



*Selected items from the collection of John H. Conway*