AIM: Building and Supporting Collaborative Research Communities

Brianna Donaldson, David Farmer, Sally Koutsoliotas, and Michelle Manes

This column is a forum for discussion of mathematical communities throughout the world, and through all time. Our definition of "mathematical community" is the broadest: "schools" of mathematics, circles of correspondence, mathematical societies, student organizations, extracurricular educational activities (math camps, math museums, math clubs), and more. What we say about the communities is just as unrestricted. We welcome contributions from mathematicians of all kinds and in all places, and also from scientists, historians, anthropologists, and others. Submissions should be uploaded to https://submission.nature.com/new-submission/283/3 or sent directly to Marjorie Senechal, MathCommunities@gmail.com.

Mathematicians love to collaborate! Who doesn't want to be on a team trying to accomplish something with fellow collaborators who can understand what we are talking about!" Those are the words of Brian Conrey, executive director of the American Institute of Mathematics (AIM), founded in 1994 by tech entrepreneurs John Fry and Stephen Sorenson. Inspired by Fry's formative experiences playing team sports plus his days as a mathematics major at Santa Clara University, AIM was conceived as a new kind of institute focused on advancing the frontiers of mathematics through collaboration, rather than the competitive isolation that had too often been the norm of the field.

Early on, Fry persuaded Jerry Alexanderson, his former professor from Santa Clara, to serve as the chair of AIM's board of trustees. Alexanderson's far-reaching connections in the mathematics community helped recruit a distinguished advisory board to launch the new institute. Prospective board members were invited to a reception at the Joint Mathematics Meetings in San Francisco in 1995. Among them was Brian Conrey, then head of the Mathematics Department at Oklahoma State University and formerly a student of Alexanderson's and classmate of Fry's.

The board met again at MathFest in 1995 and at JMM in 1996, with Sorenson running the meetings and asking for ideas for projects. No one had much to suggest initially. Then, at the 1996 meeting, Conrey proposed that the upcoming centenary of the proof of the prime number theorem might provide an occasion for convening a conference of the world's experts on the Riemann hypothesis. This idea had come from a suggestion from Hugh Montgomery together with the Mathematical Association of America independently approaching Conrey and asking him to organize something research-focused during that year's MathFest conference, which was the first MathFest that did not involve the American Mathematical Society.

Seeking to avoid the typical conference format—a series of individual talks giving a snapshot of the current state of the field—Conrey wanted to find a way for this assembly of expertise to foster actual progress in the area. This focus led to a number of important scientific outcomes, including seeding multidecade collaborations exploring the connections between Riemann zeta functions and random matrix theory. One of the most important long-term outcomes of this early conference, however, was that it introduced several aspects of what has become known as the AIM style of workshops:

- A very specific mathematical focus and an explicit goal of making progress on unsolved problems.

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- Commissioned talks on particular topics, tools, and techniques that hold the potential for making progress on those unsolved problems, rather than talks on the speakers' latest results.
- A free-flowing discussion about open problems that leads to participants' making real progress over the following years. Over time, and through much tinkering, this evolved into AIM's "moderated problem session," a feature of every AIM workshop.

In addition to its scientific significance, the conference also created quite a splash in the broader mathematical community. The first talk, which also served as the last talk of MathFest, was given by Atle Selberg on the history of the prime number theorem. Author Marcus du Sautoy provided daily radio reports to the BBC featuring interviews with the speakers. Eventually, there would appear three books on the Riemann hypothesis inspired by the Seattle conference or one of the follow-up conference events in 1998 and 2002. And last but not least, John Fry celebrated his fortieth birthday with the conference attendees!

Interestingly, during the conference, Conrey held a meeting with all the speakers to talk with them about AIM and ask whether they considered it possible to get mathematicians to work together collaboratively. Many were skeptical, including Selberg. Nevertheless, AIM moved forward, with Conrey joining as executive director in 1997.

A New Mathematics Institute

"The goals of an AIM-style workshop," says David Farmer, director of programs at AIM, "have remained constant for more than two decades: the workshop is successful if most of the participants begin work on new problems, typically with new collaborators, and that work continues long after the workshop week."

AIM's leadership envisioned a workshop model that could reproduce this degree of success in all areas of mathematics. Their idea was that participants with common mathematical interests, but no significant history of collaboration, would spend a week at AIM working together on open problems. The expectation was not to solve the problems that week, but to initiate work that would continue long past the workshop itself and that would ultimately lead to major breakthroughs on challenging problems.

In 2002, AIM became one of the Mathematical Sciences Institutes funded by the National Science Foundation, the only institute focused exclusively on short programs and on intentionally fostering collaboration. The NSF support allowed AIM to expand and refine its idea for a new kind of workshop. At the time, many mathematicians believed that such goals were unrealistic, unattainable, and unreproducible. However, in the past twenty years, over five thousand mathematicians have participated in at least one AIM workshop. The model has become popular and is often cited as the benchmark for highly interactive, inclusive, and supportive research meetings.

How Does It Go?

"From its very beginning," writes Sally Koutsoliotas, AIM programs consultant, "AIM's approach to creating an effective workshop was clear: to bring together a diverse collection of interested researchers for a week of focused collaborative work on a set of problems curated by the organizers. While AIM's purpose was clear, the means by which to accomplish it was unknown. Armed with this gold standard, and the collective experience of its staff (also active research mathematicians), AIM set out to develop an effective model."

The AIM-style workshop, developed through a painstaking trial-and-error process over a number of years, is now recognized by the mathematics research community as an enormously effective structure for bringing together people with shared interests and having them leave with (collectively) a clearer trajectory of their field and (individually) new collaborators and a fresh set of problems. We think an AIM workshop is successful not if several problems are solved that week, but rather if participants leave having formed new collaborations to work on new problems and if major progress is made more quickly than it otherwise might have been. While the key features of an AIM-style workshop are easy to describe, the implementation is anything but simple, requiring a unique combination of fastidious attention to detail and in-the-moment flexibility. Why it works so well remains a bit mysterious; we just know that it does, with great consistency.

Two Talks Every Morning

"On Wednesday, I was asked to give a talk the next day on a paper I had studied and built on for my dissertation," recalls Michelle Manes, AIM deputy director, on her first experience at an AIM workshop in 2008. "The talk was different from any I had given before. Not only did I have a single day to prepare, but the audience kept interrupting and asking questions. Everyone really wanted to understand this piece of mathematics. They didn't want a polished talk; they wanted me to guide them through how it all worked and to see what they could take from it towards the problems they were working on."

Talks at an AIM workshop are commissioned by the organizers to "set the scene" or present a particular perspective to a potentially diverse group of participants. Only the first three days of talks are scheduled in advance; the remaining two days are determined during the workshop based on the direction the workshop takes and the interests of the participants. That means that participants are often asked on Tuesday or Wednesday to give a talk on Thursday or Friday. Of course, no one is going to give a polished presentation under those circumstances, but that's a feature and not a bug. Someone with particular expertise just explains what they know. The audience asks questions and digs into the ideas. By that point in the week, everyone has been working on problems for a while and is really engaged in the ideas. The talks have no predetermined length.

Speakers are asked to talk for about fifty minutes, but the goal is to spark questions, discussion, and conversation; so the talks generally last seventy-five minutes or more. Over the years, we have tried variations on this model. Scheduling more talks doesn't leave enough time for collaboration. But some talks are necessary for introducing the participants to one another, to bridge different areas of mathematics, and to frame many of the problems that will be tackled by working groups. Also, having a talk at 9 a.m. every day is a gentle incentive for everyone to show up on time.

Monday Afternoon Moderated Problem Session

"Something that has struck me about our moderated problem sessions is the fact that experts often disagree on small aspects of their subject," recalls Brian Conrey, AIM executive director. "The way someone holds the model of their subject in their head varies considerably over individuals. I think this speaks to the usefulness of involving several people in a collaboration. I also think that this observation must be surprising for graduate students in the audience to see."

On the first afternoon of every AIM workshop, there is a moderated problem session, during which participants collectively generate a list of open problems in the field. AIM has "rules" for how this problem session will go. For example, only the moderator can write on the board. Someone describes a problem that they might like to spend some time working on (or that they would like someone else to work on because they want to know the answer). They describe the problem from their seat, and other participants can offer suggestions, refinements, ideas, references, special cases, and so on. When the moderator thinks that the problem is clear, it is written on the board. Over the course of the afternoon (about three hours), the group may generate anywhere from eight to thirty-eight problems. A note-taker is charged with writing down careful versions of each problem, and this problem list becomes a lasting outcome of the workshop, a contribution to the current and future research community.[1] Again, the specific structure of the moderated problem session has emerged through years of experimentation. This structure simply works better than any variant we have tried: letting people write their own problems on the board, splitting into small groups to brainstorm problems independently without input from the larger group, and writing the problem as dictated rather than waiting for the conversation to shape it. All of these lead to less discussion and less compelling problem lists than the moderated version.

Tuesday Through Friday Afternoon Working Groups

As Estelle Basor, AIM consulting director, notes, "The idea [of splitting into working groups] was met with considerable resistance in the mathematical community. Participants would complain that they wanted to stay together or that they needed more talks. When they actually did form groups to work, they would see how useful it was and how they could find new problems to work on and form new collaborations that would last beyond the workshop."

Working groups are what the workshop is really about and what all of the other structure is designed to support. The morning talks offer ideas and help bridge the gap when different research communities are coming together. Monday afternoon's moderated problem session generates open problems and also gets everyone talking to each other and discussing their mathematical ideas. Then on Tuesday through Friday afternoons, working groups actually dig in to work on the problems generated through the moderated problem session.

A major concern for organizers is, "How will we form the groups? Do we do it randomly? Do we assign the groups? If we just let people choose what they work on, won't we end up with everyone working on the same problem?" Over the years, AIM has developed an algorithm that reliably creates groups of reasonable size whose members want to collaborate on a particular problem, or at least spend a few hours thinking about it. We can write out the excruciating details of how to run the algorithm (see the section "The Algorithm" below), but we can't really explain why it works. It just does. Every day after lunch (Tuesday through Friday), the organizers run the algorithm on a set of about ten problems. The list of problems might change, or it might not. The makeup of the groups might change, or it might not. But the brief period involving going over the problems and running the algorithm lets everyone find a group to work with and a problem to work on.

Friday Wrap-Up

The whole-group wrap-up can be an opportunity to discuss possible follow-up events such as another meeting or a grant proposal, or to suggest updates to the list of open problems. Most importantly, it is an opportunity to clearly articulate AIM's expectation for open and inclusive collaboration. Many of the groups will continue working on their open problems in the weeks, months, and even years to come. But the groups throughout the week can be quite fluid. It is essential that when the participants leave, there is a clear process for opting in to continue to work with a group, and that all who opt in to a group are welcome.

The Algorithm

The process of breaking into groups often causes anxiety, but once participants are in the groups, everyone is happy and excited to be working on mathematics. AIM's two-vote algorithm runs quickly, and it consistently yields reasonably sized groups working on problems they have chosen.

[1] AIM problem lists are collected at http://aimpl.org/.

Step 0: Before the whole group gathers, organizers write brief summaries of about ten problems on the board, with two columns next to the list of problems.

Step 1: An organizer says the magic phrase: "Our goal this afternoon is to break into groups of four to six people to work on problems."

Step 2: An organizer briefly describes each problem. (Most of the problems have been described in more detail during the talks or in the problem session.)

Step 3: Round 1 of voting: Everyone can vote as many times as they want. The idea is to vote for any problem you would be happy to work on that afternoon, at least for a few hours. The total number of votes is recorded in the first column.

Step 4: Round 2 of voting: Start with the problem that got the fewest votes in round one and work in reverse order to the one that got the most votes. Each person votes only once. If zero or one person votes for the problem, there is no group (and the person gets their vote back). If two people vote for a problem, they can decide whether to work together or to get their votes back. Three or more votes mean that there is a group, and the number is recorded in the second column. Problems not selected on one day may be revisited on future days; each day the vote is only for that afternoon.

Step 5: Assign a room to each group, disperse, and get to work.

Details Matter

"In advance of each workshop," writes Michelle Manes, AIM deputy director, "AIM directors have several calls with organizers at prescribed intervals. Each of these calls starts by asking organizers to tell us about the mathematics they are excited about and what they hope to tackle at the workshop. The best calls are the ones in which the organizers get excited and start talking to each other about mathematics and the AIM staff just listens. We can't be specialists in the content of most of the workshops we host; our main goal is to understand who is going to be at the workshop and what the organizers hope to accomplish during their week with us. Everything we do grows out of that."

To ensure that workshops run smoothly, AIM leadership works closely with organizers both before and during the workshop week. In the year before the workshop, we have three important calls during which all organizers and the AIM leadership talk about what they need to do to ensure the success of the week. Each call starts with a discussion of the mathematics at the heart of the workshop, then focuses on an important piece of workshop preparation, and ends with homework for the organizers.

During the first call, about a year before the workshop, the organizers tell us about their planned mathematical focus, including open questions they want the group to tackle. Then AIM directors describe the AIM workshop style, including the fact that about twenty-five percent of the participants come from an open application process. The organizers' homework is to write a clear description of the workshop for our webpage and to send us an initial invitation list with about twenty-two names on it. The application deadline is about five months before the workshop, so the second call focuses on reviewing the applicants and adding any additional invitees if there is still space in the workshop. The organizers' homework is to come up with a curated reading or resource list that might be useful for participants. About one month before the workshop, we have a final call in which we talk about what will actually happen in the first few days of the workshop, and we ask what talks would be helpful to set the stage and who could give those talks.

These calls feel like a casual conversation among colleagues planning a conference, but the timetable and the script for each call are precise and designed to keep organizers focused on what is important at each stage of the process. For workshops that are atypical in some way, we may schedule additional calls along the way to work out more complicated logistics.

During the week of the workshop, we also have three meetings with organizers: Early Monday morning, before the workshop begins, we talk about the first day and the moderated problem session that afternoon. On Tuesday, during the morning break, we go over the "algorithm" for splitting into working groups and describe how the rest of the afternoons will work. On Friday, also during the morning break, we talk about options for wrapping up the week and next steps. Again, organizers have homework each day: naming a moderator and note-taker for the problem session; coming up with a list of ten or so problems for the working groups to tackle (the most important job they have, since these afternoon working groups are the heart of the workshop); and setting expectations around how collaborations will continue.

We always tell organizers that to the extent possible, AIM will take care of the logistics for the meeting, allowing the organizers to focus on the scientific program. But in fact, we guide the organizers at every step to help them create a workshop that encourages collaboration and the exploration of ideas and will lead to real progress in the field.

Nimble & Flexible

As Estelle Basor, AIM consulting director, notes, "AIM's agility is its most important quality. It allows the institute to respond quickly to create the infrastructure needed for almost any mathematical endeavor."

Plus ça change, plus c'est la même chose

The simultaneous attention to detail and flexibility involved in developing the AIM-style workshop have enabled the AIM staff to successfully adapt the workshop model to several very different physical spaces over the years. AIM's early programs were hosted in a windowless "math warehouse" next to Fry's Electronics in Palo Alto (ca. 1998–2014).

AIM's Palo Alto location: no natural light, but filled with joyful mathematics and collaboration.

In 2014, that Fry's electronics store closed, the building that had housed AIM was sold, and AIM rather suddenly had to relocate. The staff banded together over the holidays, and in the new year, AIM activities were taking place in a "math treehouse" perched over an industrial area of San Jose (2015–2023). The space was brighter, but somehow familiar: the lecture room, the social space, the library, and the small breakout rooms for the working groups were re-created in this new location at Fry's corporate headquarters.

AIM's San Jose location: bigger and brighter, and still full of energy.

In February 2021, the closing of Fry's Electronics stores forced AIM once again to look for a new home. A long process led to a happy partnership between AIM and the new Merkin Center for Pure and Applied Mathematics at Caltech. In July 2023, AIM relocated once again, this time to a breathtaking "math oasis," with panoramic views of the San Gabriel Mountains. Things look different. The library, or at least some of it, resides on another floor of the building. Some staff offices are in nearby buildings. Moveable partitions build flexibility into the space, allowing for more small groups, more socialization, and larger gatherings for special events. Yet the feel is definitely still AIM, with groups lingering well into the evening playing games in our "family room," with ideas and excitement about mathematics flowing freely.




AIM's Pasadena location: breathtaking views and new tech, but still the same vibes.

Move Fast and Fix Things

"Best online workshop!" enthused one participant in the "Limits and control of stochastic reaction networks" virtual workshop of July 2021. "Online meetings have the hazard of lacking personal contact and interaction. The way this workshop was organized really stimulated a lot of interaction."

And a participant in the "Fusion categories and tensor networks" virtual workshop of May 2021 had this to say: "Without a doubt, it is the best online conference in which [I have] participated. Those present were all ready to talk and discuss problems. The problem list and working groups have allowed me to meet new ideas and people."

Like everything in our lives, AIM's workshop program was abruptly disrupted in March 2020 when the Covid-19 pandemic reached the United States. All in-person collaborations ceased, including AIM's workshops. At the start of the shutdown, the immediately upcoming workshops were, optimistically, postponed and not canceled. When it became apparent that in-person meetings would not be returning in the foreseeable future, AIM turned its attention to recasting the format of its focused collaborative workshops into an online setting. AIM's agility was put to the ultimate test: could we successfully adapt our highly interactive and collaborative model to virtual space?

By this time, academic meetings (including classes and conferences) had pivoted to Zoom, the de facto solution to our inability to gather in person. AIM staff had participated in Zoom workshops and conferences and had spoken with others who had also tried that route. The consensus was that the experience was less than satisfactory, with the highest praise being, "better than nothing." Since AIM's workshop style requires more collaborative elements than traditional workshops, it seemed unlikely that Zoom, by itself, would be sufficient.

Trying to find something that captured the essence of these different AIM spaces but in a virtual setting was a challenge. For a solution to succeed, participants would have to feel as though they were at a workshop at which everyone was experiencing (or enduring) the same activities (or ordeals). The instrumental idea came from Roman Holowinski, of the Ohio State University, who suggested Sococo, a virtual office environment that he had used successfully for an online REU (research experience for undergraduates) program.

Sococo looks like the floor plan of a building, with offices, medium- and large-sized meeting rooms, a lobby, and hallways connecting the rooms. We found a layout that approximates some version of AIM's physical space and proceeded to work through many iterations of adapting our in-person workshops to the virtual world. It required a

AIM's virtual home for two years: not as picturesque but still familiar.

huge investment of time and creativity, but we believe the results were worthwhile.

From August 2020 until December 2021, AIM held twenty-two virtual workshops, and many participants reported that it was their first authentic research experience during Covid. Were these online workshops as effective as the refined, well-established in-person workshops? Definitely not. But that is the wrong question. During Covid, everyone was working from home and had constant distractions. Such an environment is not conducive to sustained periods of focused research. Coupled with unavoidable time zone issues, there was a limit to what one could expect. But the combination of Sococo, a suite of other tools that interact well within its virtual environment, and a dedicated staff enabled AIM's virtual workshops to succeed in providing an environment in which a group of mathematical researchers could begin working collaboratively on interesting problems and have that work continue long after the workshop was over.

New Opportunities

Leslie Hogben, AIM associate director for diversity, has this to say about AIM's newest program: "The slower pace and lack of travel make this AIM Research Community model ideal for faculty at small undergraduate colleges with high teaching loads or scientists in industry who want to remain active in research of their choosing."

As the pandemic has begun to subside, we have mostly returned to in-person activities. However, in the success of our online workshops, AIM saw the potential for a new model of supporting research collaborations with larger groups over a longer time period using a virtual environment to foster a sense of community. In 2021, AIM launched a new program, AIM Research Communities. Intended to support larger collaborative efforts involving at least forty people, Research Communities are organized around a particular area of mathematics research. Some Research Communities function like extended AIM workshops, with occasional talks, a large moderated problem session, and splitting into groups via the "algorithm." The

smaller groups self-organize, meeting approximately weekly. The whole group may host social events, panel discussions, "virtual office hours," graduate student reading groups, or any number of other activities via the Sococo platform.

Currently, AIM supports nine research communities representing a breadth of disciplinary interests. Each community supports different activities and gathers in a variety of ways that reflect their community's goals, but common to all is the inclusion of a diversity of participants who engage in focused collaborative research, albeit remotely.

Joyful Collaborative Mathematics Guides Our Work

"AIM's openness to trying new things and to fostering collaboration has resulted in people from the math community involving us in all sorts of interesting projects over the years," writes Brianna Donaldson, AIM director of special projects.

Collaboration is a formidable ingredient in any setting. AIM's experience with organizing disparate groups to work collectively on difficult problems has been fruitful in establishing other successful programs, including the following.

The Structured Quartet Research Ensemble (SQuaREs) program supports the formation of small collaborative teams of fout to six people to work on ambitious projects for a week, with the possibility of returning for a second and third week in subsequent years. While this model grew naturally from productive collaborations arising from prior AIM workshops, it has strong appeal to the entire mathematical research community.

AIM's Math Circle Network (MCN) is a national organization serving as a hub for several hundred locally organized math circles. Math circles are mathematical problem-solving communities that are organized collaboratively by K-12 teachers and mathematicians. These communities come in two main varieties: circles for teachers and circles for students. The MCN began after the first math teachers' circle (MTC) was launched with an AIM workshop in the summer of 2006, organized by a group of local teachers and mathematicians who recognized the need for teachers to have a professional space in which they could interact with colleagues around mathematics. That workshop was funded with the stipulation (put forward by AIM's executive director Brian Conrey) that the organizers help disseminate MTCs through a second workshop the following year. In total, AIM has so far organized sixteen workshops on "How to Run a Math Teachers' Circle" and has developed significant online resources to help build capacity for teams around the country to begin their own local MTCs. In January 2020, we took on the challenge of incorporating math student circles into the MCN as well, with the hope of better connecting student and teacher math circles and expanding access to both types of programs.

The Open Textbook Initiative has been vigorously supported by AIM from its beginning in 2010 to the present day. AIM's institutional focus on collaborative research spread naturally to fostering the development and improvement of open educational resources. The textbook initiative has been a part of the larger UTMOST project (Undergraduate Teaching of Mathematics with Open Software and Textbooks), funded by the NSF in three phases since 2010. AIM has provided support for the Open Textbook Initiative in various ways, including hosting the project's website and publicizing its work through our booths at Joint Mathematics Meetings and MathFest.

The front and back of the Alexanderson Award medal.

Celebrating Our Success and Our Legacy

Carl Friedrich Gauss, speaking through Google Translate, says, "It is not knowing but learning, not possessing but acquiring, not being there but getting there, which grants the greatest enjoyment."

Jerry Alexanderson had an enormous influence on the mathematics profession. He was the Mathematical Association of America's president, vice president, and secretary; a professor at Santa Clara University; winner of the Deborah and Franklin Haimo Award for Distinguished College or University Teaching of Mathematics and the Yueh-Gin Gung and Dr. Charles Y. Hu Award for Distinguished Service to Mathematics; editor of *Mathematics Magazine*; coauthor, editor, or coeditor of 15 books; and author or coauthor of over 130 articles and reviews. He was also the founding chair of AIM's board of trustees, and his impact on AIM is similarly enormous and long-lasting.

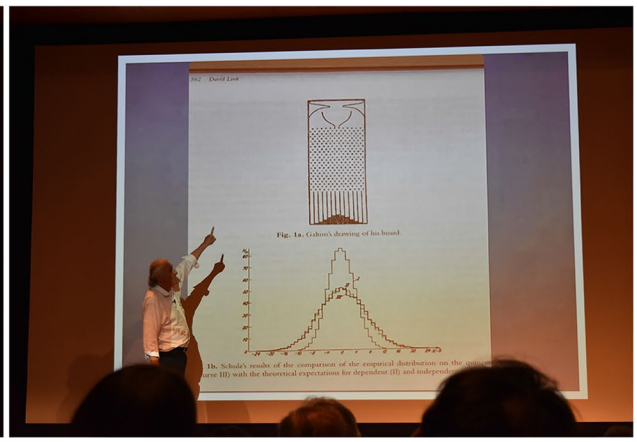
In 2018, AIM instituted the Alexanderson Award to honor Jerry's legacy and importance to our work. The award was John Fry's idea, and it was in the works even before Jerry retired from Santa Clara University. Since AIM already collects information about the papers and preprints resulting from AIM activities,[2] it was natural to select an outstanding paper for the award. John's vision was to give a medal with Jerry's picture on it, and he found the Gauss quotation above, which encircles the picture (in the original German). The plan was a medal in the shape of a regular 17-gon as a nod to one of Gauss's early mathematical accomplishments in the straightedge-and-compass construction of that figure. Unfortunately, no one could create such a medal, so we settled on a more traditional circular shape. The back of the medal has the names of the winners along with a piece of the mathematics from their paper.

The award is unique in mathematics for at least two reasons: It fundamentally celebrates a successful collaboration. And the prize includes a trip to Bock Cay, in the Bahamas.

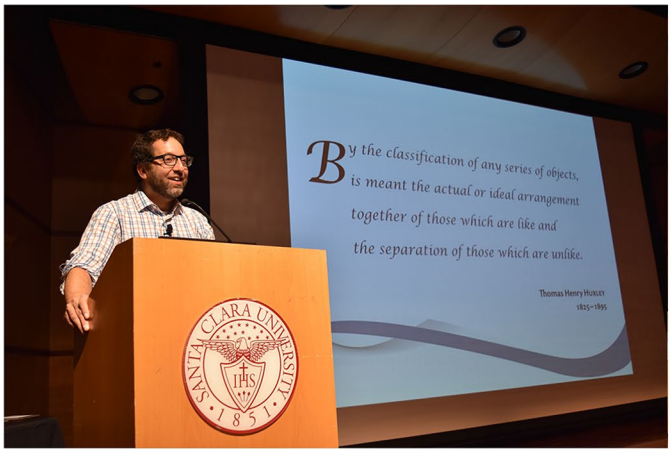
[2]The AIM preprint list can be found at https://aimath.org/preprints/. The AIM publication list is at https://aimath.org/publishedpapers/

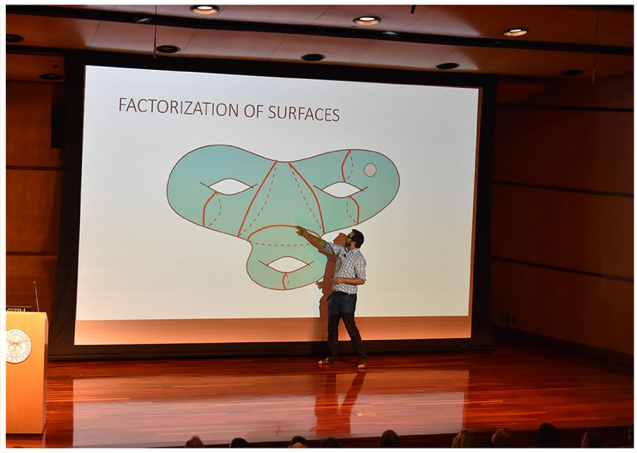
Clockwise from top left: Bock Cay from the air, the 2020 awardees on the island, and the 2018 awardees (with AIM executive director Brian Conrey, their families, and some iguanas) on the beach.

Santa Clara University agreed to host the Alexanderson Lecture and prize ceremony each year. In 2023, AIM became a partner in the Joint Mathematics Meetings (JMM), so the award and lecture moved to JMM to allow for wider recognition of the awardees and greater awareness in the mathematics community of the impact of AIM's work.

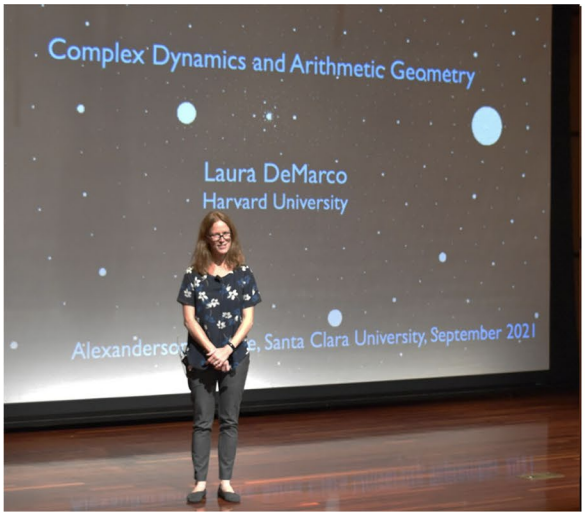


Top: Persi Diaconis giving the first Alexanderson Award lecture. Bottom: Brian Conrey (AIM executive director), Ivan Corwin, Alexei Borodin, Keith Devlin (chair of AIM's advisory board), Patrik Ferrari, and Persi Diaconis.





Top: Jordan Ellenberg giving the second Alexanderson Award lecture. Bottom: Estelle Basor (AIM deputy director), Zhenghan Wang, Eric C. Rowell, Siu-Hung Ng, Paul Bruillard, and Brian Conrey (AIM executive director).



Welcome

This evening of mathematics is a celebration in memory of Jerry Alexanderson. The Alexanderson Award and Lecture recognizes outstanding research in mathematics and achievements in mathematical exposition.

The award is given for an outstanding research article arising from work at AIM, where Jerry Alexanderson was the founding chair of the Board of Trustees. The public lecture recognizes Jerry Alexanderson's personal commitment to furthering public understanding of mathematics and its impact on our world through his sixty years at Santa Clara University.

Professor Gerald L. "Jerry" Alexanderson

Gerald ("Jerry") Alexanderson, a member of the Santa Clara University faculty since 1958 and chair of the AIM Board of Trustees, died on December 16, 2020. During his time at Santa Clara, he was chair of the Mathematics department for 35 years and a member of the Faculty Senate Council. For thirty eight years he held the endowed Valeriote Professorship of Science chair. Known as an inspiring teacher and popular author, Alexanderson cultivated a passion for problem solving and creative thinking. He was the author of more than a dozen books, including textbooks in abstract algebra, and discrete and combinatorial mathematics. Alexanderson was the first recipient of Santa Clara University's Bayma Award for Scholarship, and he received the Special Appreciation Award from the Dean of Arts and Sciences as well as the Special Recognition Award for Teaching, Research, and Service from the President of the university.

His influence was instrumental in AIM's history and development from the beginning more than 25 years ago and continuing to this day. Just as he inspired students, Jerry inspired AIM to have workshops that emphasized problem solving and collaborations and he encouraged AIM to build an extensive library of important papers and books. However, Jerry's contribution to mathematics extended far beyond his association with AIM, especially his leading and lasting role in the Mathematical Association of America (MAA). His contributions to the MAA spanned more than 50 committees and 24 years on the Board of Governors, encompassing secretary, vice-president, and president of the Association and editor of Mathematics Magazine. Results of this work include the remodeling of the MAA Carriage House in Washington, D.C., into its Mathematical Sciences Conference Center. In this time, Jerry served on the Science Policy Committee of the American Mathematical Society (AMS) and was a consultant to the Editorial Board for the Bulletin of the AMS. In testament to his expansive record, Alexanderson received the MAA's most prestigious award for distinguished service to Mathematics, the Yueh-Gin Gung and Dr. Charles Y. Hu award.

The Alexanderson Award

Uniform Manin-Mumford for a family of genus 2 curves

Laura DeMarco, Holly Krieger, and Hexi Ye are the recipients of the 2020 Alexanderson Award for their paper, "Uniform Manin-Mumford for a family of genus 2 curves," which was published last year in the Annals of Mathematics. The paper grew out of the AIM SQuaRE, Dynamical Andre-Oort Questions.

In this paper, they study the geometry of surfaces and how each sits inside a 4-dimensional torus, called its Jacobian. There is a large set of special points in this Jacobian, its "torsion" points; but in the early 1980s, Raynaud proved that the surface will intersect only finitely many of these points.

This finiteness statement was called the Manin-Mumford conjecture. Soon after, Mazur posed an important question about these surfaces, asking if one can bound the number of the special points on the surface only in terms of its genus (the topology of the surface), or if there is additional geometric information one needs to know to control the size of this intersection.

Award Winners

Laura DeMarco

Laura DeMarco is a professor of Mathematics at Harvard University. She earned her Ph.D. in 2002 from Harvard, and her undergraduate degree in mathematics and physics from the University of Virginia. DeMarco was elected to the National Academy of Sciences in 2020 and was awarded the Satter Prize from the American Mathematical Society in 2017. DeMarco's research is focused on the dynamics of polynomials and rational mappings, especially in dimension one, with the primary goal of understanding notions of stability and bifurcation. Her recent work explores connections between dynamical systems and arithmetic geometry.

Holly Krieger

Holly Krieger earned her bachelor's degree in mathematics at the University of Illinois at Urbana-Champaign and her master's and PhD from the University of Illinois Chicago. She was a postdoctoral fellow at the Massachusetts Institute of Technology. Krieger toured Australian universities as the Australian Mathematical Society 2019 Mahler Lecturer. She was the recipient of a London Mathematical Society 2020 Whitehead Prize. She makes regular appearances on the popular YouTube channel Numberphile.

Hexi Ye

Hexi Ye is a Professor of Mathematics at the Department of Mathematics of Zhejiang University. He received his Ph.D. from the University of Illinois at Chicago in 2013. His interests include complex dynamics and arithmetic dynamics. In particular, much of his research is concerned with unlikely intersection problems in dynamics, such as Dynamical Manin-Mumford conjecture and the uniform boundedness for the number of common preperiodic points of two rational maps.

The Alexanderson Lecture | Laura DeMarco

Title: Complex Dynamics and Arithmetic Geometry

In this talk, I will present a connection between the theories of dynamical systems and arithmetic geometry. Building on a simple relation — between periodic points for a particular class of systems in dimension 1 and the torsion points for the group structure on a 2-dimensional complex torus — I will describe some ideas that went into my joint work with Holly Krieger and Hexi Ye about the geometry of algebraic curves in genus 2. Some of these same ingredients, namely dynamical equidistribution and arithmetic height bounds, were used this year in a major breakthrough by Lars Kuhne, proving uniform versions of Faltings' Theorem (the Mordell Conjecture) and of Raynaud's Theorem (the Manin-Mumford Conjecture).

Clockwise from top left: Laura DeMarco giving the third Alexanderson Award lecture, Laura DeMarco receiving her medal from Brian Conrey, and the program from the award ceremony.

Left: Stephen S. Kudla giving the Alexanderson Award lecture at the 2023 JMM in Boston. Right (from left to right): Brian Conrey (AIM executive director), Jan Bruinier, Tonghai Yang, and Stephen S. Kudla at the 2023 JMM Prize ceremony.

Left: Joni Teräväinen giving the Alexanderson Award lecture at the 2024 JMM in San Francisco. Right (from left to right): Brian Conrey (AIM executive director), Terence Tao, and Joni Teräväinen at the 2024 JMM Prize ceremony.

Alexanderson Award Winners

2018 awardees: Alexei Borodin, Ivan Corwin, and Patrik Ferrari.

Paper: "Free energy fluctuations for directed polymers in random media in 1+1 dimensions," *Communications in Pure and Applied Mathematics*, 2014.

AIM activity: October 2011 workshop, "The Kardar–Parisi–Zhang equation and universality class."

Lecture: Wednesday, December 12, 2018, at Santa Clara University.
Persi Diaconis, "Universality & the Taming of Randomness."

2019 awardees: Paul Bruillard, Siu-Hung Ng, Eric C. Rowell, and Zhenghan Wang.

Paper: "Rank-finiteness for modular categories," *Journal of the American Mathematics Society*, 2016.

AIM activity: March 2012 workshop, "Classifying fusion categories."

2019 awardees: Paul Bruillard, Siu-Hung Ng, Eric C. Rowell, and Zhenghan Wang.

Lecture: Friday, October 4, 2019, at Santa Clara University.
Jordan Ellenberg, "Breaking Up Is Hard to Do."

2020 awardees: Laura DeMarco, Holly Krieger, and Hexi Ye.

Paper: "Uniform Manin–Mumford for a family of genus 2 curves," *Annals of Mathematics*, 2020.

AIM activity: 2016–2019 SQuaRE, "Dynamical Andre-Oort Questions."

Lecture: Thursday, September 30, 2021 at Santa Clara University.
Laura DeMarco, "Complex Dynamics and Arithmetic Geometry."

2022 awardees: Jan Bruinier, Benjamin Howard, Stephen S. Kudla, Michael Rapoport, and Tonghai Yang.

Paper: "Modularity of generating series of divisors on unitary Shimura varieties," *Astérisque*, 2020.

2022 awardees:	Jan Bruinier, Benjamin Howard, Stephen S. Kudla, Michael Rapoport, and Tonghai Yang.
AIM activity:	2014–2016 SQuaRE, "Modularity of Generating Series for Special Cycles."
Lecture:	Friday, January 6, 2023, at JMM in Boston. Stephen S. Kudla, "Modularity of Generating Series of Divisors on Unitary Shimura Varieties."
2023 awardees:	Kaisa Matomäki, Maksym Radziwiłł, Terence Tao, Joni Teräväinen, and Tamar Ziegler.
Paper:	"Higher uniformity of bounded multiplicative functions in short intervals on average," *Annals of Mathematics*, 2023.
AIM activity:	December 2018 workshop, "Sarnak's conjecture."
Lecture:	Thursday, January 4, 2024, at JMM in San Francisco. Joni Teräväinen, "Uniformity of the Möbius Function in Short Intervals."

What's Next?

It's hard to know how to wrap up a story about AIM, since the story has just begun a new chapter. AIM's work continues, and it will continue to evolve. But here are some of what AIM's staff said when they were asked to look back and to look forward.

> Something I am very happy about is the fact that the number of women in our workshops has steadily increased over time. During our first NSF site visit before the 2002 grant award I said out loud that our goal was for 20% participation by women in our workshops. That was met with comments such as "That is a laudable goal but not possible to achieve." Now that percentage is close to 30% (Brian Conrey, AIM executive director)

> If you attend an AIM workshop or an AIM SQuaRE, you will notice that there is an openness to ideas that is often missing in other settings. Participants feel free to ask questions of any sort, talk to colleagues, and suggest ideas and approaches to problems. There is a liveliness and a sense of motion and often wonder in the air (Estelle Basor, AIM consulting director)

> As an outsider who is becoming an insider, I've been thinking about what makes AIM and its work so special. One thing that has struck me time and again is AIM's culture of listening. It's baked into everything we do, and it's becoming more and more clear to me how much it's a defining property of the institution. (Michelle Manes, AIM deputy director)

> It didn't take long before I fell in love with the impact MTCs were clearly having. Teachers would tell us that our workshops changed their entire view of mathematics, helping them identify as "math people" and seeing that their students could be successful in math, too. Mathematicians spoke of being rejuvenated by reconnecting with "fun" mathematics and of getting inspired to transform the way they taught their undergraduate classes. We saw local communities form, and watched friendships and collaborations grow. It felt meaningful in a way that nothing in my graduate school experience ever had. (Brianna Donaldson, AIM director of special projects)

> Several mathematics institutes have in-house libraries, but just one or two have an on-site rare book collection. Of these, only AIM routinely offered tours … most were deeply engaged, full of questions and comments and I nearly always came away having learned something new. In short, the Thursday tours were reflective of AIM: a mutual give-and-take between speaker and audience and an enriching experience for all. (Ellen Heffelfinger, AIM librarian)

> Having the AIM name and reputation behind the initiative has been of great benefit in convincing the mathematics community of the value and quality of open educational resources. (Kent Morrison, AIM editorial board and system administrator)

> Every program at AIM, whether it be for the oldest of tenured professors, to the youngest of kindergarteners, pushes the idea that mathematics is a collaborative sport … AIM is the Math Community for everyone by everyone to everyone. (Tyler Knapp, AIM operations assistant)

We hope to see you in Pasadena soon!

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