Autumn 2016

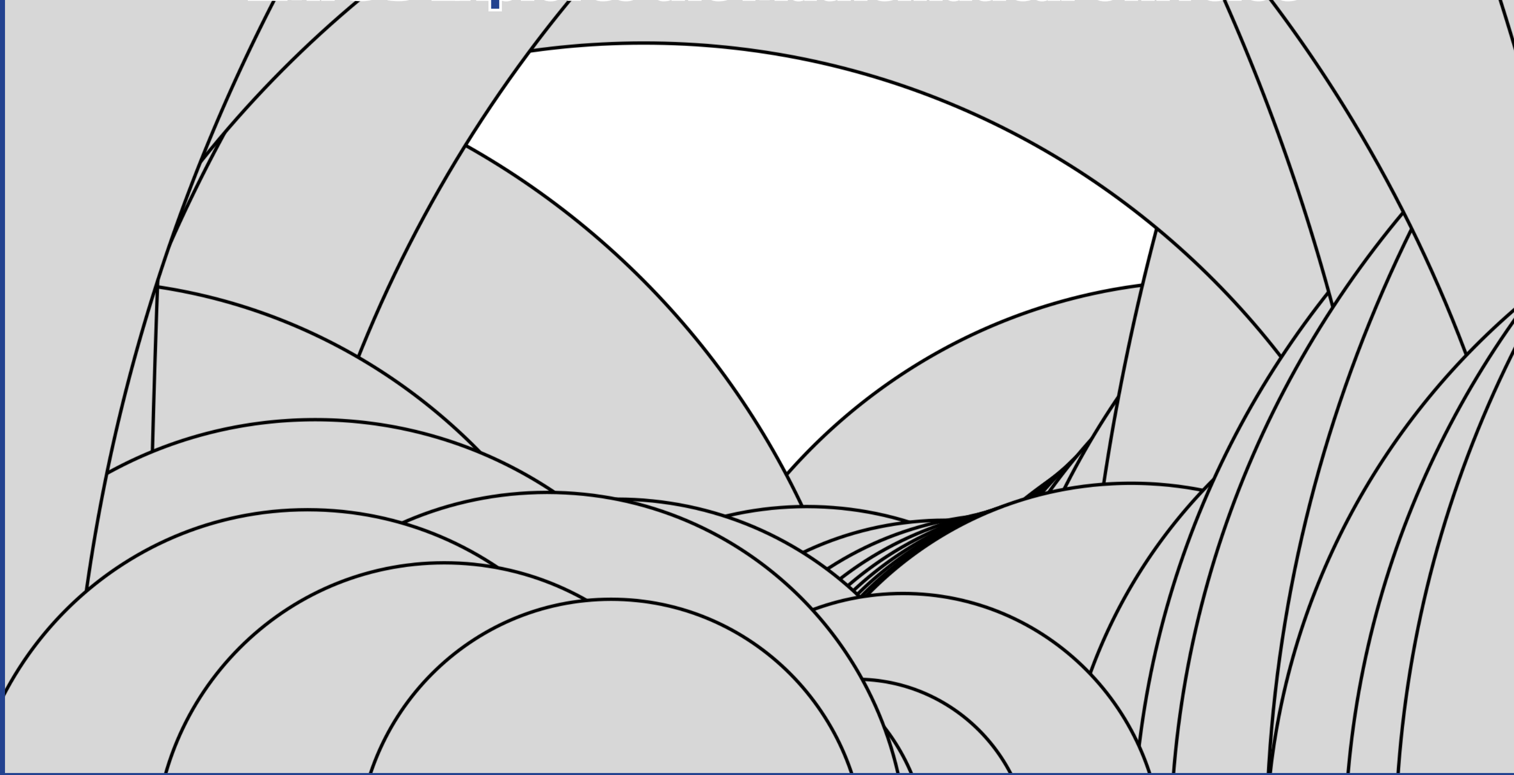
AIMatters

Newsletter of the American Institute of Mathematics

Bridges Between Worlds
From Past to Present

To Guatemala and Beyond
Julia Robinson Math Festivals Travel Abroad

Collaborating Worldwide
LMFDB Explores the Mathematical Universe



Letter from the Director

Greetings from San Jose

We are enjoying our new space! Each week our participants are treated to elegant lunches prepared by chefs Matt DeLosso and Richard Tamura. In the evenings they can enjoy downtown nightlife via a short ride on the light rail, then rest comfortably at the lovely DoubleTree hotel near the San Jose airport. And they are doing great math! So far this year our workshop and SQuaRE participants have written nearly 80 papers based on their work at AIM; see our preprint server **www.aimath.org/preprints/**.

Now that we can host four SQuaRE groups at a time, our long-term plan is to have 20 research workshops per year, and 20 weeks of four SQuaREs per year, or 1000 visitors each year. It is exciting to have so much amazing and diverse math.

I especially want to thank Fry's Electronics for their continued support of AIM: our space and its maintenance; the van used to shuttle our participants to and from the hotel; and many other intangibles. The financial support we have received from Fry's, the Fry Family Foundation, and from the PGA as the host institution for the Frys.com golf tournament over the past nine years has been indispensable for our programs. Thank you to everyone involved!

It is impossible to describe all the math happening at AIM in one newsletter. But here you'll read about interesting developments in a new area of mathematics called "Topological Recursion." Also, the REUF program, a joint project with the Institute for Computational and Experimental Research in Mathematics (ICERM), received a new four-year grant from NSF.

There are now over 100 Math Teachers' Circles (MTCs) around the country! Congratulations to the MTCs for being included in the prestigious national 100Kin10 initiative. And our math teams in Morgan Hill were exceptional in their competitions this year. The Julia Robinson festivals are gaining in popularity; there have been more than 30 of them in the past year!

The L-functions and Modular Forms database, which had its origins at AIM, came out of beta! Its goal is to chart the first millions of L-functions, with their low lying zeros and special properties. Nearly 90 people have worked to accomplish this! You can see the results at **www.lmfdb.org**. Be sure to read the news section, and watch the "busy bees" video linked under social media.

We are happy to welcome new appointees to our Scientific Board: Georgia Benkart, Kate Juschenko, Russell Lyons, and Gigliola Staffilani.

It has now been 20 years since the first AIM event I took part in: the meeting that began with Atle Selberg's lecture on the history of the prime number theorem on August 12, 1996, as the final event of the Seattle MathFest and the first event of the AIM-sponsored conference, "In celebration of the centenary of the proof of the prime number theorem: A symposium on the Riemann Hypothesis." I remember the event fondly, and I think it started a chain reaction that got AIM to where it is today. See the 1996 conference announcement at **www.aimath.org/research/conferences/rh-conf.html**. ■

Brian Conrey

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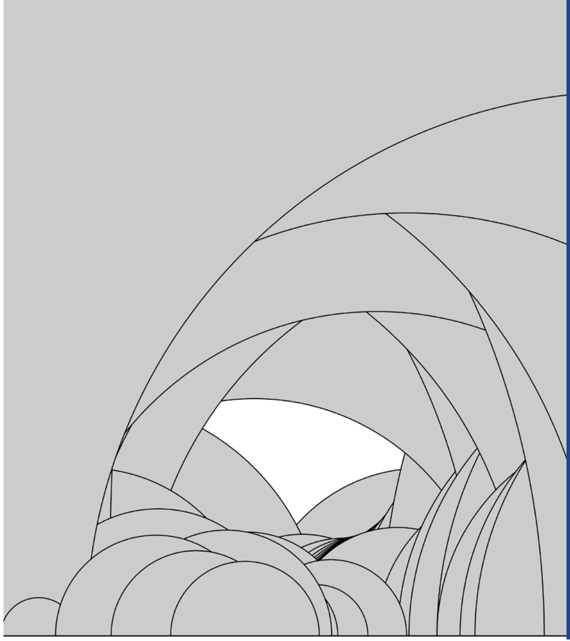


ABOUT THE COVER IMAGE

A famous dynamical system, the so-called Douady Rabbit, is determined by a piece of geometric data which may be thought of as a point in the complex upper half-plane. A new computer program, NETmap, estimates the location of this point—the white region shown—using purely combinatorial methods.

This computer program was developed in part during the AIM SQuaRE, "The global dynamics of Thurston's pullback map," with participants William Floyd, Gregory Kelsey, Sarah Koch, Russell Lodge, Walter Parry, and Kevin Pilgrim, who sought to classify the particular dynamical systems known as nearly Euclidean maps.

For more information, visit www.math.vt.edu/netmaps/.

Bridges Between Worlds

From Past to Present

A small section of the Song dynasty painting "Along the River During the Qingming Festival" by Zhang Zeduan. The original Rainbow Bridge features prominently in the middle of this 12th-century Qingming Scroll.

It is said that in Song Dynasty China (960-1279), scholars hypothesized that rainbows were formed by a phenomenon of sunlight encountering droplets of rain in the air. Historians assert that during those years the population of China grew to about 100 million people. With the expansion of the waterways, bridges had to be developed so that people could get from one side of the river to the other in a safe manner. It is in the Shandong province, a mountainous terrain where previous bridges had often washed away in spring floods, where a Rainbow Bridge was first developed by a retired prison guard. This bridge over the Bian Canal in Kaifeng, resembling a rainbow, spanned a waterway without having any central pillars that could be washed away by the floods.

In *Interaction between mathematics and physics*, British geometer Nigel Hitchin explains that "both communities of mathematicians and physicists are alive and evolving, and aiming at discovery, but their backgrounds and motivations differ. This diversity is a source of strength if the two groups can focus on a common problem." It is indeed through collaborations between these disciplines that bridges between mathematics and physics are built.

A very important mathematical idea that has been a pillar for bridges between mathematics and physics is the one of Higgs bundles, first studied by Nigel Hitchin in 1987. Higgs bundles and the corresponding Hitchin fibration have found applications in many different areas, among which one should mention gauge theory, Kähler and hyper-Kähler geometry, surface group representations, integrable systems, non-abelian Hodge theory, mirror symmetry, and *F*-theory. More recently, Higgs bundles were used to give a physical derivation of the geometric Langlands correspondence, and together with the Hitchin fibration were a key ingredient in the proof by Ngô of the fundamental lemma, a crucial component of the number-theoretic Langlands program which led Ngô to the Fields Medal in 2010.

Mesmerising links between mathematics and physics that have appeared in the theory of Higgs bundles are beautifully described in Olivia Dumitrescu and Motohico Mulase's *Lectures on the topological recursion for Higgs bundles and quantum curves* [arXiv:1509.09007], and it brings us back to rainbows. In the XIXth century, in an attempt to explain the rainbow phenomena in terms of wave optics, Sir George Biddel Airy devised what he called the *rainbow integral*,

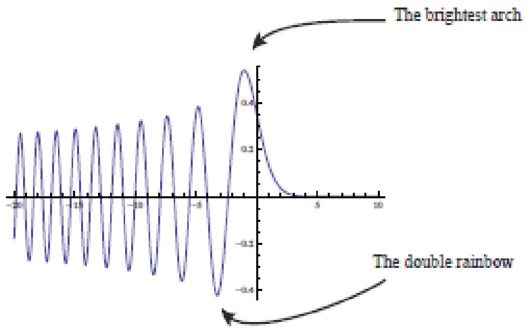
$$Ai(x) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{ipx} e^{ip^3/3}\, dp \,,$$

and which now carries his name.

The angle between the sun and the observer of a rainbow measured at the brightest arch is always about 42°. The higher arches also have certain fixed angles, independent of the rainbow. Airy tried to explain these

Photo: Zhuwq, commons.wikipedia.org.

angles and the brightness of the rainbow arches by the peak points of the rainbow integral.



The Airy function satisfies a second order differential equation (known as the Airy differential equation).

$$\left(\frac{d^2}{dx^2} - x\right) Ai(x) = 0.$$

The above equation has a convergent power series expansion satisfying a limiting formula, which is closely related to certain intersection numbers. This relation was discovered by Kontsevich in the early 1990s, when he showed that the matrix Airy function counts trivalent ribbon graphs through the Feynman diagram expansion, which represent open dense subsets of the compactification of the moduli space of genus *g* curves with *n* marked points.

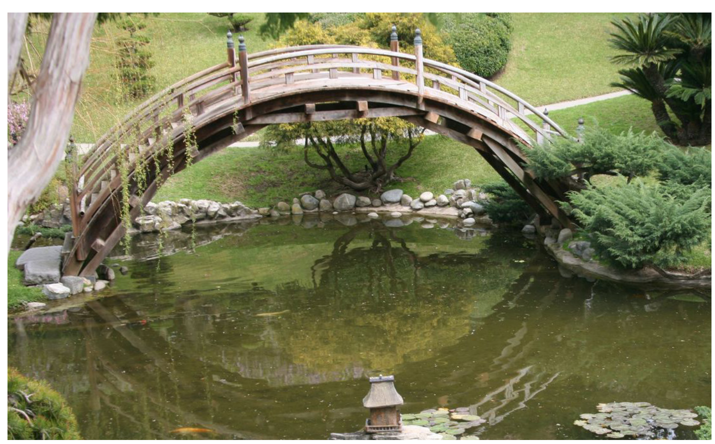
Those intersection numbers can be calculated through topological recursion, and as shown by Dumitrescu and Mulase, they can also be obtained as the asymptotic expansion of a function that comes from the geometry of the spectral curve of a Higgs field. In their work, the Airy differential equation is identified as a quantum curve, and the application of the semi-classical limit and topological recursion enables them to calculate generating functions of the intersection numbers. The topological recursion is exactly the same as the *Virasoro constraint conditions* for the intersection numbers, and the semi-classical limit recovers the spectral curve of the corresponding Higgs bundle.

Much of the progress described here can be attributed to a series of AIM workshops and SQuaREs, which helped accelerate the breakthroughs that occurred in the understanding of the geometry and physics of topological recursion and Higgs bundles. These activities brought together researchers from very different areas of mathematics and physics. One highlight from the most recent AIM meeting was a working group composed of researchers with diverse backgrounds, many of whom had never met before, who used their geometric insights and physical intuition to solve a variant of one of the open questions in the field. By the end of the week, Olivia Dumitrescu, Laura Fredrickson, Georgios Kydonakis, Rafe Mazzeo, Motohico Mulase, and Andy Neitzke sketched a paper with new ideas, which in turn positively settled a conjecture of Gaiotto that had been standing for years.

In addition, the community of mathematicians studying Higgs bundles and related topics highly benefited from the AIM goal of broadening participation. Indeed, AIM hosted the first *"Current trends on spectral data for Higgs bundles"* weekend meeting in September 2015. At this workshop 85% of the speakers, and half the audience, were young female mathematicians. As one participant explained, "This type of forum with emphasis on young/female researchers has an important role to play in the development of the field."

In the end, this series of workshops and SQuaREs also brings us back to building bridges, not only bridges between fields, but bridges to greater inclusion in the mathematics community. ■

– Laura P. Schaposnik



Commonly referred to as a "rainbow bridge" or "moon bridge," this wooden style is thought to be similar to the original Rainbow Bridge in Kaifeng.

Photo: Stacy Barnett, 123rf.com

To Guatemala and Beyond

Julia Robinson Math Festivals Travel Abroad

During 2015-16, AIM's partner, the Julia Robinson Mathematics Festival, returned to many long-term venues and hosted new festivals in the US and beyond. Over the course of the year, 34 festivals took place in 12 U.S. states, as well as China, India, and Guatemala, reaching over 5,500 students. Texas A&M at College Station, University of Tulsa, and Shippensburg University hosted festivals for the first time this year.

JRMF's collaborative, non-competitive style, as well as its challenging problems and mathematical puzzles, were a hit with participants as a welcome supplement to conventional classroom offerings. "This is what math should be like in school," commented one participant at Stanford. "I now know that math is much more than just numbers," said a student in New Delhi.

As part of its ongoing outreach to educationally underserved students, JRMF also brought the festival to schools such as KIPP Summit School in San Lorenzo, CA, and Murphy Elementary School in Richmond, CA. Said Murphy School event organizer Catherine Malicdem:

> *I could not have imagined how wonderful the math festival was going to be. Parents who attended were so happy their student was able to experience something so fun, dynamic, and educational. I heard 'thank you' so many times that day and it was clear that JRMF has to be an annual event at Murphy! The Julia Robinson Math Festival is inspiring, uplifting, and encouraging.*

Plans are now in progress for 2016-17 festivals, which got under way with a JRMF at the National Museum of Mathematics in New York City on Friday, September 16, 2016. And if you would like to bring a festival to your school or community, send an email to **info@jrmf.org** for resources and support. ■

– *Mary Eisenhart*

From top: A sign welcoming JRMF to Guatemala. Students enjoying mathematical puzzles and games. The dedicated and enthusiastic volunteers who made the Festival a great success.

Research Abounds

The Sky's the Limit for REUF

Several exciting developments have made this a banner year for the Research Experiences for Undergraduate Faculty (REUF) program. First among these is that NSF has awarded AIM and Institute for Computational and Experimental Research in Mathematics (ICERM) collaborative grants for REUF. The grants will complete a decade of REUF workshops, funding four REUF workshops and associated small research group follow-up meetings. The grants also make official the longstanding partnership between AIM and ICERM in hosting REUF activities. The principal investigators for the new grants are Leslie Hogben, AIM Associate Director for Diversity; Brianna Donaldson, AIM Director of Special Projects; and Ulrica Wilson, ICERM Associate Director for Diversity.

This summer brought two REUF workshops instead of the usual one. The regular REUF workshop was hosted at the new AIM facility in San Jose for the first time, with research groups led by Ruth Haas (Smith College), Loek Helminck (North Carolina State University), and Mark Ward (Purdue University). In addition, the Information Initiative at Duke (iiD) partnered with REUF to offer a workshop entitled "REUF on the Mathematics of Data." The workshop focused on the interface of pure mathematics and big data analytics, with research topics including Information Theory, Combinatorics, and Abstract Algebra (led by Robert Calderbank, Duke); Topological Data Analysis (Paul Bendich, Duke); and Geometric Insights in Machine Learning (Sayan Mukherjee, Duke). During the workshop, faculty also interacted with undergraduates concurrently participating in iiD's successful Data+ REU program and learned about a wide variety of data science projects amenable to undergraduates. According to AIM Executive Director Brian Conrey, "We are excited to partner with Duke to disseminate the REUF model and think that the 'big data' focus will be immensely appealing to many undergraduate faculty and their students."

REUF was designed to enhance the ability of faculty at undergraduate colleges and universities to engage their students in research, and this continues to be a major emphasis. Over time REUF has also evolved to serve as a research renewal program for some faculty participants, engaging them in long-term research collaborations and developing expertise in new areas that are accessible to undergraduates. Three of the 2015 REUF research groups have continued their work through meetings this year. One group, led by Leslie Hogben (Iowa State University and AIM), is continuing their study of two related graph coloring parameters, one of which arose from designing monitoring systems for electric power networks. Another group, led by Ami Radunskaya (Pomona College), is working on a new approach to modeling a dendritic cell cancer vaccine. The third group, led by Glenn Ledder (University of Nebraska-Lincoln), is continuing to develop a model for onchocerciasis, a tropical disease caused by a parasitic worm. Faculty research will be showcased in two special sessions at the Joint Mathematics Meetings in January 2017, both organizaed by REUF alumni. ■

– Leslie Hogben

Panel discussion at the 2016 REUF workshop at AIM.

Collaborating Worldwide

LMFDB Explores the Mathematical Landscape

One of the larger projects that began at AIM is the L-functions and Modular Forms Database (LMFDB). The LMFDB is both a website (available at www.LMFDB.org) and a collaboration that has grown to include 90 people worldwide. The work is another example of AIM's mission to foster large-scale collaboration in the mathematical sciences.

The project began nine years ago at the AIM workshop "L-functions and modular forms," which brought together mathematicians who, individually, had generated a lot of interesting mathematical data. The workshop's goal was to combine their data to create a new type of resource for researchers. There were many problems to be solved: everyone had a different format for their data; some data were on web pages, and others were just in files on a laptop; most of the calculations were incomplete; and no one person had a detailed understanding of all the objects and their inter-relationships. The workshop ended with plans to seek funding to help extend the existing calculations and begin combining everything into a common repository.

> ***"Our project is akin to the first periodic table of elements. We have found enough of the building blocks that we can see the overall structure and begin to glimpse the underlying relationships."***
> ***–John Voight, Dartmouth***

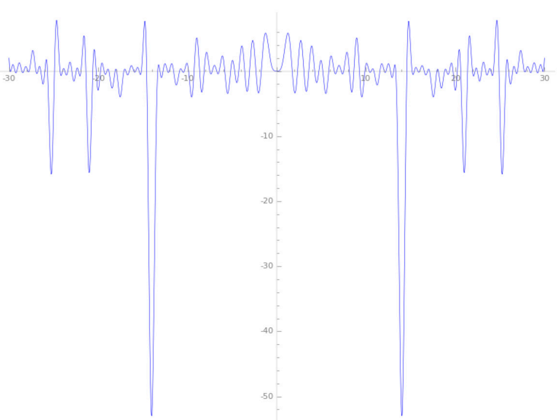
With the help of Focused Research Group (FRG) and Cyber-enabled Discovery and Innovation (CDI) grants, both from the National Science Foundation (NSF), work on the LMFDB website began at a workshop in the Fall of 2010. At that workshop, two key principles were adopted that have guided development over the past six years:

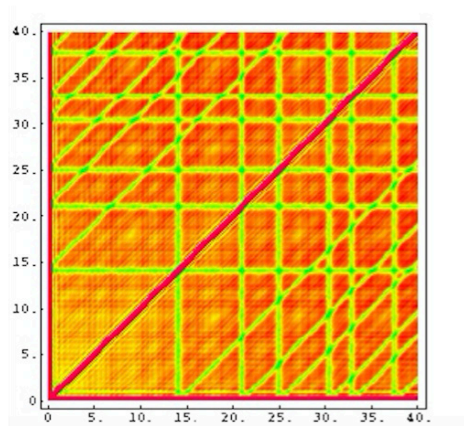
- every object has a "home page," and
- each home page has a mathematically meaningful permanent web address.

For example, the L-function of the elliptic curve $y^2 = x^3 + 4$ can be found at www.LMFDB.org/L/EllipticCurve/Q/108.a/.

What goes on the home page of a mathematical object? The same information as goes on your own home page: your name, basic information about yourself, your picture, links to your friends, and so on. The home page analogy forces the experts in each area to clearly articulate which data should be associated to each object, which information is most important, and what are the object's "friends."

The need for a permanent web address forces the entire group of LMFDB collaborators to come together to understand the relationships between several areas of mathematics and to give a good label to every object in every area. These decisions take considerable effort, because both the experts and the nonexperts in each





Left: The Z-function of the first rank 4 elliptic curve. The "fangs" are due to the influence of the zeros of the Riemann zeta function. Image courtesy of LMFDB. Right: The triple correlation of the zeros of the Riemann zeta function. The stripes are due to the influence of the first few zeros of the Riemann zeta function on the later zeros. Image courtesy of Nina Snaith.

area have to reach a consensus on how to classify each set of objects. And for the same reason, these discussions are both educational and rewarding, because you feel that you really understand an object once you know its defining characteristics and its proper place in its environment.

By the end of 2015, the LMFDB had grown to include around 20 different types of objects, some of which had millions of examples. The decision was made to officially announce the website, which until then was publicly available but still in its "beta" release. But how to tell people about the project? Do we focus on a few of the objects? List them all? Give examples of some interesting ones or stress the connections between different objects? Do we talk about the technological hurdles we had to overcome, or the mathematical ones? Or maybe we should stress the human aspect: 90 people building a huge website over the course of six years is not common in mathematics.

In the end, more than 15 separate press releases were made by the universities and institutions of LMFDB collaborators. Each told the story from its own perspective, with much sharing of well-turned phrases and interesting quotes. Here are a few extracts from those press releases:

"The LMFDB is really the only place where these interconnections are given in such clear, explicit, and navigable terms. Before our project it was difficult to find more than a handful of examples, and now we have millions."

(Holly Swisher, Oregon State University)

"An L-function can be shared by different objects, so there can be a connection between two once disparate objects through this underlying 'DNA.' "

(Nathan Ryan, Bucknell University)

"Most of us are aware of these relationships in an abstract way, but it takes real work to actually figure out all the details."

(Andrew Booker, University of Bristol, UK)

"You can find rare and hard-to-produce items that can let a researcher or student study something they didn't know existed or that would be impossible to reproduce on their own."

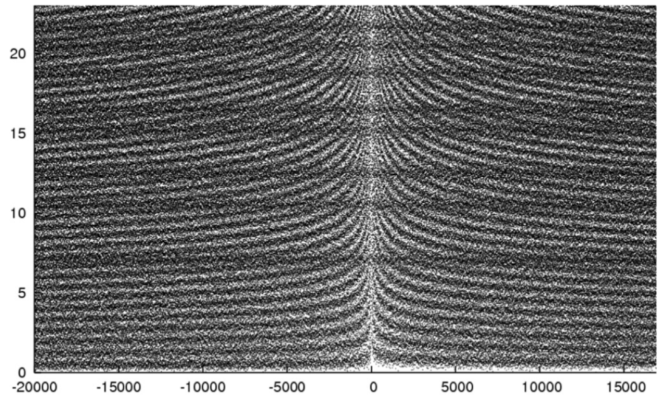
(Christelle Vincent, University of Vermont)

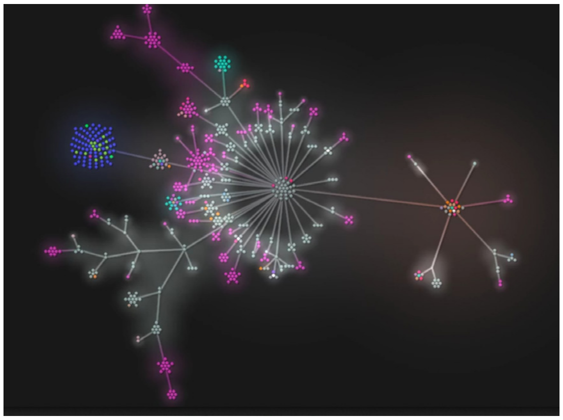
"The LMFDB is both an educational resource and a research tool which will become indispensable for future exploration."

(Brian Conrey, AIM)

The LMFDB will continue to grow, adding more extensive data on the objects it has cataloged, and expanding into new areas. ■

– David Farmer





Left: The zeros of 10,000 different L-functions. The curved white regions are called "sand dunes" by Michael Rubinstein, who discovered them. The darker horizontal bands are the shadows of zeros of the Riemann zeta function. Image by Michael Rubinstein. Right: The current state of the LMFDB source code displayed as a tree with the root directory of the project at its centre. Directories appear as branches, with files as leaves. Image by Gource.

Dispatches from Morgan Hill

Students Rise to the Top

The 2015-16 school year was another huge success for Morgan Hill students involved in Morgan Hill Math's various programs. Morgan Hill Math is an outreach program sponsored by AIM that brings math enrichment to fourth through twelfth grade students who live in or around Morgan Hill and are looking for mathematical challenges outside of the normal school curriculum.

Fourth and fifth graders involved in the eight week Mathletics program enjoyed hands-on lessons that included discovering pi, proving that the angles of a triangle always add up to 180, and an introduction to the complexities of solving Sudoku, among other fun topics. Sixth graders put on their detective caps to solve puzzles using proportions, permutations, and combinations. They also worked to solve open-ended problems based on Dan Meyer's popular Three Act Math Tasks such as the Penny Pyramid. The most dedicated students were invited to participate in the international Math Olympiad program. For most students, this was their first taste of math competition. Additionally, interested sixth graders were encouraged to challenge themselves by competing in the AMC8.

Once again, Morgan Hill Math benefitted from a Tensor SUMMA grant to assist underrepresented minorities in attending our programs. The grant enabled us to provide transportation to classes when needed, after-school care and mentoring prior to classes, and to purchase scientific calculators for students who needed them. Many of these students lack computers and internet access at home, so we were able to use these funds to purchase six Chromebooks and hold a summer computer workshop for these students.

The cornerstone of AIM's Morgan Hill Math is the MATHCOUNTS classes for seventh and eighth graders. Weekly coaching sessions were held at three of the local schools and a centralized location from September through December. This was a standout year for our students! Silicon Valley Flex Academy and the Charter School of Morgan Hill came in first and second in the team round at the MATHCOUNTS chapter competition, qualifying the eight students to compete at the Northern California State Competition held at Stanford University in March. Joining them were two other Morgan Hill students from Oakwood Country School who also qualified as individuals.

Both Ann Sobrato High School and Live Oak High School have a chapter of the national math honors society, Mu Alpha Theta, through which students are invited to take the American Mathematics competitions, AMC10 and AMC12. For the fourth year in a row, the Sobrato Math Club students ran a Science Alive class, on Tessellations, at Gavilan College for sixth through eighth grade students. Parth Shah led Sobrato's math club last year. Parth is an amazing, dedicated math enthusiast who spends many hours tutoring his fel-

Left: 2015-2016 Math Olympiad winners. Right: Coach Kelley Barnes with Neil Shah and Antarish Rautela after the MATHCOUNTS chapter competition.

low students in math. He received the highest score in Morgan Hill on the AMC12, was selected for a $4000 Mu Alpha Theta scholarship, and received a Regents Scholarship to UC Berkeley where he will major in Computer Engineering.

Live Oak's Mu Alpha Theta Club received an exciting boost, with the arrival of new co-advisor, Beth Kochuparambil. Beth is as an engineer at Cisco Systems, the mother of two young children, and active in ministries that help teenagers. Not only does Beth bring her passion for math and leadership to the club, but she has also brought in several of her peers for lunchtime talks about careers in the STEM field.

Under Beth's guidance, Live Oak Mu Alpha Theta teens sharpened their math skills in the once-a-month Continental Math League competition and the AMC10 and AMC12. Julia Leal, Live Oak's math club student president, is on her way to Stanford next year.

Perhaps one of the biggest benefits of our Morgan Hill Math programs has been the personal connections that have been made between the students and the coaches. Lori Mains mentors eight girls whom she met through AIM's Tensor SUMMA program, helping them at various times with science projects, homework, or scholarship applications. Two of the eighth graders are shining stars, with one winning a scholarship to a STEM camp at Stanford this summer, and another girl being sponsored for a trip with Britton Middle School's Volcano Club to Costa Rica this past spring.

Kelley Barnes has been working extensively with two young math enthusiasts, Antarish Rautela and Neil Shah. After two years of training, these sixth grade boys were finally old enough to compete at the MATHCOUNTS chapter contest in 2016, where they placed first and second in the individual competition. These friends are so closely matched that they also placed second and first in the Jeopardy-style, Countdown round at the competition! They have also both won the George Lenchner Award for perfect scores in the Math Olympiad, and had the two highest scores in Morgan Hill on both the AMC8 and the AMC10. They are continuing their math training throughout the summer, hoping to improve their scores in the MATHCOUNTS state competition next March.

Three accomplished middle school math aficionados were invited to work directly with Dr. Brian Conrey, Executive Director of AIM, in our Director's Circle. Antarish, Neil, and seventh grader, Claire Huang, spent four evenings being challenged by Dr. Conrey with the inclusion-exclusion principle, a method to quickly distinguish a prime number from a composite one, and the expansion of a binomial term raised to a fractional power. It is so exciting to see the abilities of these outstanding math students! ■

– *Kelley Barnes*

Left: Antarish Rautela, Dr. Conrey, Claire Huang, and Neil Shah. Right: Morgan Hill students and coaches who attended the MATHCOUNTS competition in February 2016.

AIM Scientific Board
Welcomes New Members

The AIM Scientific Research Board welcomes four new members this year. They are Georgia Benkart, Kate Juschenko, Russell Lyons, and Gigliola Staffilani.

Georgia Benkart is Professor Emerita at the University of Wisconsin and an Associate Secretary of the American Mathematical Society. Her research interests are in Lie algebras, representation theory, combinatorics, and noncommutative algebra. She received her Ph.D. from Yale University under the direction of Nathan Jacobson.

Russell Lyons is the James H. Rudy Professor of Mathematics at Indiana University. His research interests range across a number of topics in probability theory. He received his Ph.D. from the University of Michigan.

Kate Juschenko has recently joined the faculty of Northwestern University. Her research work focuses on amenable groups and more generally on probabilistic and geometric problems in group theory. She received her Ph.D. from Texas A&M.

Gigliola Staffilani is the Abby Rockefeller Mauze Professor of Mathematics at MIT. Her main research interests are in partial differential equations and harmonic analysis. She received her Ph.D. from the University of Chicago.

Plans to Expand

Math Teachers' Circles Extend their Reach

Math Teachers' Circles (MTCs) bring teachers together with mathematicians in a professional environment for mathematical problem solving. The goals are to engage teachers in thinking deeply about mathematics and to build a community of mathematics professionals dedicated to improving education for all students.

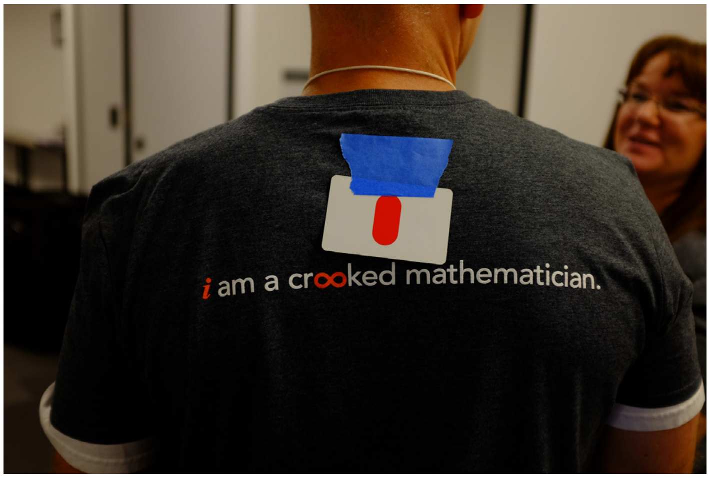
Founded at AIM in 2006, the Math Teachers' Circle Network helps start new MTCs across the U.S. and provides organizational resources to support their activities. Our vision is for every teacher in the United States to have access to a Math Teachers' Circle.

This spring, the MTC Network was selected as a partner in 100Kin10, a national network coordinating and accelerating efforts to grow the science, technology, engineering, and math (STEM) teaching force. The MTC Network is one of 49 new partners to join a network of now over 280 of the country's top businesses, nonprofits, foundations, and academic institutions to help achieve the goal of 100,000 excellent STEM teachers by 2021.

"We are honored to have been selected as a new 100Kin10 partner," said Brianna Donaldson, Director of the MTC Network. "Our passion at the Math Teachers' Circle Network is to build strong professional communities of mathematics teachers who challenge all of their students to become problem solvers. Being part of 100Kin10 is a tremendous opportunity for us to share ideas and learn from the experience of other organizations committed to excellent STEM education."

As part of 100Kin10, the MTC Network has committed to reach 6,000 teachers and their 600,000 students by growing its national network to 300 Math Teachers' Circles by 2020. Currently there are 109 active Math Teachers' Circles across the U.S.

Through the support of its sponsors, AIM is developing regional infrastructure that will allow the Math Teachers' Circle Network to expand to 300 sites by 2020. In four different states—California, Montana, North Carolina, and Ohio—AIM has helped facilitate collaboration among nearby groups through facilitator exchanges, summer workshops, and seed funding.



A participant at the summer immersion workshop of the Crooked River Math Teachers' Circle in Cleveland, OH.

In the past 12 months, AIM has helped launch 17 new Math Teachers' Circles, including our first-ever international Circle. We are excited to welcome the following Circles to the Network:

- Blue Ridge MTC (Asheville, NC)
- Central North Carolina MTC (Salisbury, NC)
- Coastal Carolina MTC (Conway, SC)
- Crooked River MTC (Cleveland, OH)
- CSU Dominguez Hills MTC (Carson, CA)
- Inland Empire MTC (San Bernardino, CA)
- Fort Lewis College MTC (Durango, CO)
- Ithaca MTC (Ithaca, NY)
- Montana MTC at Great Falls (Great Falls, MT)
- Montana MTC at Helena (Helena, MT)
- Montana MTC at Billings (Billings, MT)
- Portland MTC (Portland, OR)
- Southwest Chicago MTC (Romeoville, IL)
- Southwest Florida MTC (Fort Meyers, FL)
- Summit County MTC (Akron, OH)
- United Arab Emirates MTC (Abu Dhabi, UAE)
- Mahoning Valley MTC (Youngstown, OH)

If you'd like to start a Math Teachers' Circle in your area, please contact **circles@aimath.org** for information and support. ■

– Hana Silverstein

Shaping the History of Math

New Reprints Offer Deep Insight

Last summer, AIM acquired the considerable reprint collections of two men with perhaps little in common, other than degrees in mathematics from Cambridge and Oxford, and the coincidence that each nearly singlehandedly revived a neglected discipline.

The first is H.S.M. (Donald) Coxeter (1907-2003), whose collection comes to us from York University. A British-born Canadian mathematician, Coxeter is regarded as the greatest geometer of the twentieth century, known for Coxeter groups, Coxeter numbers, and Coxeter diagrams, among many celebrated inventions. In a mathematical climate that revered "all things austere, abstract, and algebraic,"[1] he eloquently advocated and advanced a classical approach to geometry, with spectacular results that reinvigorated the field. Near the end of a long life, he was commemorated in both book and documentary as "the man who saved geometry."[2]

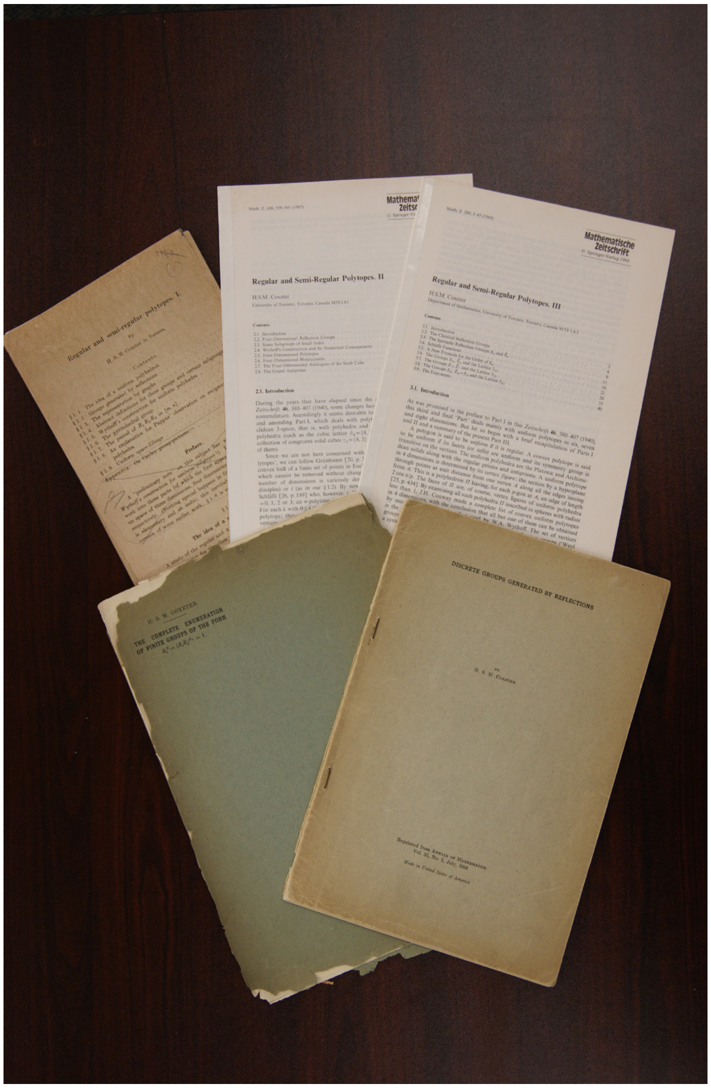
Similarly, Ivor Grattan-Guinness (1941-2014), the renowned British historian of mathematics and logic, consciously sought to rescue a moribund area of mathematics. As reported in the Guardian:

> *When Ivor Grattan-Guinness… became interested in the history of mathematics in the 1960s, it was an area of study widely considered to be irrelevant to mathematics proper, or something that older mathematicians did on retirement. As an undergraduate at Oxford, he found that mathematics was presented drily, with no inkling of the original motivations behind its development. So Ivor set himself the task of asking, "What happened in the past?" – as opposed, he said, to taking the heritage viewpoint of asking, "How did we get here?"*[3]

A prolific writer who specialized in the development of the calculus and mathematical analysis and in the rise of set theory and mathematical logic, Grattan-Guinness placed mathematics firmly in its historical context. His meticulous and widely praised histories and bibliographies are essential tools for mathematical historians, researchers, librarians, and collectors. We are indebted to Enid Grattan-Guinness for her donation and to Albert Lewis, who initiated and facilitated the transfer of material.

AIM is very much the richer for these additions to its library. Numbering in the thousands, the Coxeter and Grattan-Guinness reprints offer deep insight into both the influences that shaped these two mathematicians and the work that they produced over long careers. ■

– Ellen Heffelfinger



A selection of H.S.M. Coxeter offprints

1. Siobhan Roberts, *King of Infinite Space.* New York: Walker Books, 2006.
2. Ibid.
3. Tony Crilly, "Ivor Grattan-Guinness," The Guardian, December 31, 2014.

THANK YOU

AIM gratefully acknowledges the following donors for their generous contributions of books, reprints, journals, and archives to the AIM library in 2015 and 2016:

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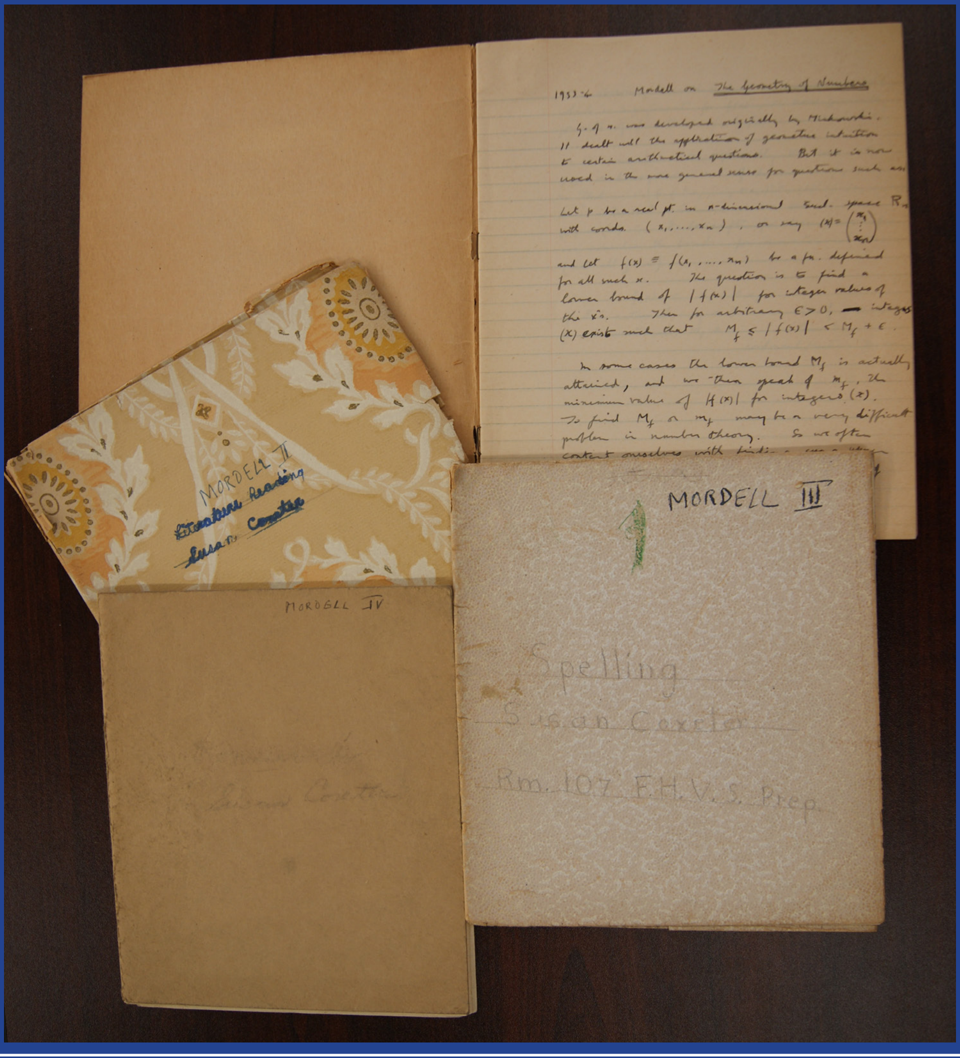

H.S.M. Coxeter's manuscript notes on Mordell's "Geometry of Numbers," inscribed in his daughter's school exercise books