Indiana University Department of

Mathematics Alumni Newsletter

College of Arts & Sciences Alumni Association

Chair's Corner

Elizabeth Housworth

I am honored to be serving as chair of the Department of Mathematics at Indiana University Bloomington. Throughout this edition of the newsletter, you will see the accomplishments of our previous chair, Kevin Zumbrun, who served us for the past five years, as well as the accomplishments of members of the department under his leadership. Here I want to tell you about the department's continuing goals and some of my own goals for the coming years.

(continued on p. 3)

Problem Corner

Problem 1: An IU basketball player misses his first free throw of the season, but later his free throw percentage rises to greater than 80%. Was his shooting percentage exactly 80% at some intermediate time?

(continued on p. 18)

Has the ABC-conjecture been proven?

About a powerful conjecture which is easy to state and hard to prove.

It's all about $A + B = C$. This conjecture is about positive integers A, B, and C which satisfy the simple equation $A + B = C$. Furthermore, we will only be interested in those triples which have no common prime factors, in which case we say that A, B, and C are coprime. For instance,

$$\begin{aligned} 1 + 8 &= 9 \\ 4 + 121 &= 125 \\ 100 + 243 &= 343 \\ 104 + 625 &= 729 \end{aligned}$$

While it is no problem to generate plenty of triples (A, B, C) with the property that $A + B = C$, there is something special about the examples just given. Namely, in these examples, all of the above numbers contain powers of relatively small prime numbers:

$$\begin{aligned} 1 + 2^3 &= 3^2 \\ 2^2 + 11^2 &= 5^3 \\ 2^2 \cdot 5^2 + 3^5 &= 7^3 \\ 2^3 \cdot 13 + 5^4 &= 3^6. \end{aligned}$$

As a measure which prime numbers actually occur in such an equation, we consider the so-called *radical* $\mathrm{rad}(ABC)$, which is defined to be the product of all prime numbers dividing one of the numbers A, B, or C. In the above examples we have

$$\begin{aligned} \mathrm{rad}(1 \cdot 8 \cdot 9) &= 6 \\ \mathrm{rad}(4 \cdot 121 \cdot 125) &= 110 \\ \mathrm{rad}(100 \cdot 243 \cdot 343) &= 210 \\ \mathrm{rad}(104 \cdot 625 \cdot 729) &= 390 \end{aligned}$$

What makes the above examples special is that in each case we have $C > \mathrm{rad}(ABC)$, as can be checked immediately. The *ABC-conjecture* asserts that this rarely happens. More precisely:

ABC-conjecture. *For any given* $\varepsilon > 0$ *there are only finitely many triples* (A, B, C) *of positive coprime integers satisfying* $A + B = C$ *and such that*

$$C > \mathrm{rad}(ABC)^{1+\varepsilon}.$$

In order to compare C and $\mathrm{rad}(ABC)$ we consider the *quality* of the triple (A, B, C) which is defined to be

$$q(A, B, C) = \frac{\ln(C)}{\ln(\mathrm{rad}(ABC))}.$$

In the above examples we have

$$\begin{aligned} q(1, 8, 9) &= 1.23 \\ q(4, 121, 125) &= 1.03 \\ q(100, 243, 343) &= 1.09 \\ q(104, 625, 729) &= 1.11 \end{aligned}$$

Using the quality of a triple we can give an equivalent formulation of the

ABC-conjecture. *For any given $\varepsilon > 0$ there are only finitely many triples (A, B, C) of positive coprime integers satisfying $A + B = C$ and such that*

$$q(A, B, C) > 1 + \varepsilon.$$

For example, the current world record[1] for quality is 1.63 and is held by the triple $2 + 3^{10} \cdot 109 = 23^5$. And there are only 236 triples known with $q > 1.4$. To get a feel for the conjecture, the reader may try[2] to find triples (A, B, C) whose quality is greater than 1. They are surprisingly hard to find, and there are exactly six such triples[3] with $C < 100$.

ABC implies other deep results. The *ABC*-conjecture is a very powerful conjecture in the sense that, if indeed true, it implies other deep number theoretic results. For instance[4], let us consider Fermat's Last Theorem[5] which states that for $n \geq 3$ there are no triples of coprime positive integers (a, b, c) such that $a^n + b^n = c^n$. Put $A = a^n$, $B = b^n$, $C = c^n$. Then we find

$$\begin{aligned} q(A, B, C) &= \frac{\ln(c^n)}{\ln(\mathrm{rad}(abc))} \\ &= n\frac{\ln(c)}{\ln(\mathrm{rad}(abc))} \geq n\frac{\ln(c)}{\ln(c^3)} = \frac{n}{3}. \end{aligned}$$

Therefore, for all $n \geq 4$ together there can only be finitely many solutions to the Fermat equation $a^n + b^n = c^n$. As the case $n = 3$ has been shown by Euler, the *ABC*-conjecture tells us that Fermat's Last Theorem is true, up to possibly finitely many exceptions.

Is ABC known to be true? In August 2012 Shinichi Mochizuki from the Research Institute for Mathematical Sciences in Kyoto released four papers, *Inter-universal Teichmüller Theory I-IV*, on his home page, claiming that these papers would establish, among others, a variant of the *ABC*-conjecture, namely that $\ln(ABC) \leq (3 + \varepsilon)\ln(\mathrm{rad}(ABC)) + K_\varepsilon$, where the constant K_ε only depends on ε. This variant is called the *weak ABC-conjecture*, but it is equally a very strong statement and a proof would be a major achievement, comparable with the works for which Fields Medals have been awarded. These four papers total more than 500 pages, and in them Mochizuki makes use of several earlier papers he has written. It is not only the sheer amount of pages, but anyone who attempts to understand in detail what the author is doing here also has to digest the very many new concepts he introduces. Though some experts started to study his papers shortly after they appeared, it seems that the mathematical community has not yet reached a conclusion about the validity of Mochizuki's work[6].

The starting point: from triples to elliptic curves. How would one ever go about proving such a conjecture? The starting point is actually a construction with which number theorists are familiar: the Frey-Hellegouarch elliptic curve[7]. Given a triple (A, B, C) we consider the curve

$$E_{A,B} : y^2 = x(x - A)(x + B).$$

This curve had already been used by Andrew Wiles in his work related to Fermat's Last Theorem (in which case $A = a^n$ and $B = b^n$). The key observation is that the so-called *discriminant* $\Delta(E_{A,B})$ is (essentially) $(ABC)^2$ and the so-called conductor $N(E_{A,B})$ is (essentially) $\mathrm{rad}(ABC)$. A conjecture of Lucien Szpiro for general elliptic curves E now states

$$\ln(|\Delta(E)|) \leq (6 + \varepsilon)\ln(N(E)) + K_\varepsilon.$$

[1] according to `http://www.math.leidenuniv.nl/~desmit/abc/index.php?set=2`

[2] The website `http://abcathome.com/conjecture.php` offers some online program to do so.

[3] cf. `https://www.phfactor.net/abc/index.php`, this is another nice webpage to explore.

[4] A detailed discussion of the connection between the *ABC*-conjecture and other results and conjectures, such as the Mordell-conjecture can be found in the article *It's As Easy As abc* by Andrew Granville and Thomas J. Tucker, Notices Amer. Math. Soc. **49** (2002), no. 10, 1224–1231.

[5] which is, in fact, a theorem of Andrew Wiles

[6] Certain mistakes have also been found in his papers, but Mochizuki claims to have corrected them and released a "progress report" in December 2013.

[7] named after Gerhard Frey and Yves Hellegouarch who considered them independently in the late 1960's and early 1970's

And this implies, by the observation just made, the weak form of the *ABC*-conjecture mentioned above. What Mochizuki aims to prove is in fact this conjecture of Szpiro about elliptic curves.

Evidence: ABC for polynomials. What evidence is there for the conjecture to be true, apart from computer-based experiments? That integers behave in several respects similar to polynomials (in one variable) has been the source of a great number of analogies in Algebra and Number Theory. And indeed, the analogue of the *ABC*-conjecture for polynomials is the following theorem of R. C. Mason (from 1984):

Mason's Theorem. *Let $a(t), b(t), c(t) \in \mathbb{C}[t]$ be coprime non-constant polynomials satisfying $a + b = c$. Then*

$$\deg(c) \leq \deg\left(\mathrm{rad}(abc)\right) - 1,$$

where $\mathrm{rad}(abc)$ is the monic polynomial of minimal degree that has the same roots as $a(t)b(t)c(t)$.

By its definition, the polynomial $\mathrm{rad}(abc)$ has only simple roots, and $\deg\left(\mathrm{rad}(abc)\right)$ is thus the number of distinct roots of abc, which is denoted below by $N_0(abc)$. While we do not have a proof of the original *ABC*-conjecture, Mason's Theorem is not *that* hard to prove, and below we give a particularly elegant proof due to Professor Noah Snyder. It is interesting to note that the proof given below uses differentiation. This is actually a key feature which is not available for integers. (What is the derivative of, say, 9?) And indeed, the lack of differentiation is *the* obstacle that Mochizuki tries to overcome by developing his theory. Vaguely speaking, it is the action of a *Galois group* which is supposed furnish a replacement for differentiation.

Proof of Mason's Theorem.[8] Let (a, b) denote the greatest common divisor of polynomials and let $N_0(f)$ be the number of distinct roots of a polynomial f. Then we have

$$N_0(f) = \deg f - \deg(f, f').$$

This is proved by factoring f into linear terms and using the product rule.

Since $a+b = c$, taking the derivative yields $a' + b' = c'$. Multiply the first equation by a' and the second equation by a and subtract to get $a'b - ab' = a'c - ac'$. Thus $a'b - ab'$ is divisible by each of the gcds (a, a'), (b, b'), (c, c'). Since a, b, and c are relatively prime we also see that

$$(a, a')(b, b')(c, c') \mid a'b - ab'.$$

Since the right hand side is nonzero, we have that the degree of the left hand side is less than or equal to the degree of the right hand side. Thus:

$$\begin{aligned}\deg(a, a') + \deg(b, b') + \deg(c, c') \\ \leq \deg a + \deg b - 1.\end{aligned}$$

Rearranging we see that

$$\begin{aligned}\deg c \leq (\deg a - \deg(a, a')) + \\ (\deg b - \deg(b, b')) + \\ (\deg c - \deg(c, c')) - 1 \\ = N_0(abc) - 1.\end{aligned}$$

□

by MATTHIAS STRAUCH

[8] N. Snyder, *An alternate proof of Mason's theorem.* Elem. Math. **55** (2000), no. 3, 93-94.

Chair's Corner

continued from page 1

Our Director of Undergraduate Studies, Kevin Pilgrim, will teach a new course, Careers in Mathematics, in Spring 2015. The course will inform sophomores and juniors about career opportunities that make use of their mathematics degree. We need your help. What has your mathematics degree enabled you to do? You can share your story with us at: https://www.iub.edu/~mathdept/math-alum-form/math-alum-form.php

Distinguished Professor Michael Larsen founded the Bloomington Math Circle in 2008 and has run this outreach program single handedly since then. It is time for the Department of Mathematics at Indiana University to contribute to this important endeavor. In the Summer of 2014, two of our Senior Lecturers, Tracy Whelan and Andrew Dabrowski, will attend the week long Math Circle Summer Teacher Training Institute at Notre Dame run by Bob and Ellen Kaplan, the organizers of The Math Circle in Boston. The workshop will have demonstrations of the Kaplans' approach, practice sessions in running Math Circles, discussions of theory and practice, and conversations about selected math topics. Participants will work with children in 1st through 12th grades each afternoon to try out their own Math Circle ideas. Drs. Whelan and Dabrowski will bring their expertise back to Bloomington and assist the department in creating a Math Circle for local children with the help of our undergraduate majors, graduate students, post doctoral students, lecturers, faculty, and

visitors.

We have a record incoming graduate class for Fall 2014 consisting of 38 students, 11 of whom are women. With the support of then Department Chair, Professor Zumbrun, and the College, our Director of Graduate Studies, Matthias Weber, provided 27 of these incoming students a fellowship for at least one semester. Exciting new opportunities await these students. Professors Michael Larsen and Hari Bercovici have created Problem Solving courses in Algebra and Analysis in order to help students get comfortable with the type of problem solving and communication of ideas needed to conduct research in mathematics. These courses will run for the first time in the coming 2014-15 academic year. Professor Weber has developed a Research Experiences for Graduate Students course to push the students even further towards developing research independence.

I owe a special thanks to Associate Dean for the Sciences, David Clemmer. He has provided funding so that we can increase the number of women speaking in the department's research seminars during the 2014-15 academic year. He has also been instrumental in bringing to Indiana University Bloomington Gioia Di Cari's Truth Values: One Girl's Romp through M.I.T.'s Male Math Maze. His eloquence on promoting women in the sciences secured funding for this performance from the Provost's office. The Assistant Dean for the Sciences, Jo Anne Tracy, has worked tirelessly to secure a venue, to promote the performance, and to plan a discussion forum following the play. Professor and Chair Jonathan Michaelson of Theatre, Drama, and Contemporary Dance has generously provided a venue for this performance. This acclaimed monologue tells, in a humorous, poignant, and uplifting way, Gioia's challenges of being a female PhD student in the M.I.T. Mathematics Department in the 1980's. We are still in the process of scheduling, but we aim to bring this performance to Bloomington in late Spring or early Fall, 2015.

The Secretariat of the American Mathematical Society approved our proposal to host a Central Sectional Meeting in Bloomington in the Spring of 2017. Sectional meetings have grown in recent years and now typically involve around 400 participants. These meetings provide a wonderful opportunity for our students and faculty to showcase their work, learn about the recent work of others, and network with the regional mathematical community. Our meeting will take place April 1-2, Saturday and Sunday, in 2017. The department thanks Mary Morgan at Indiana University Conferences for helping with our proposal and for her future work making our meeting a success.

I am pleased to announce that Professor Alexander Volberg, currently at Michigan State University, will be joining us in Fall 2015 as our Charlotte Ann Griffin Professor. We will profile his distinguished career in the next newsletter. Finally, I look forward to working energetically on behalf of the department for the next three years.

About the Newsletter

I am indebted to the 2013-14 newsletter committee, Kent Orr, Jim Davis, and Matthias Strauch, for their help writing and compiling articles for this edition. I have reformatted our newsletter into LaTeX, which enables the inclusion of mathematical notation in these articles.

Student News

From DUGS Kevin Pilgrim:

Indiana University Mathematics continues to attract the finest students on campus. We now have a record number of undergraduates, at 399, and vital Math and Actuary Clubs.

Employers in nearly every profession seek mathematicians for their acknowledged intelligence and creativity. Recent graduates now attend graduate programs in Mathematics, Biomedicine, Chemistry, Cognitive Psychology, Education, Finance, Neuroscience, Optometry, and Physics, as well as professional programs in Medicine and Law. To name a few, they have jobs at CNO Financial Group, The Nielsen Company, The Boeing Company, BMO Capital Markets, the United States Air Force, Fitch Ratings, The Mind Trust, ProCure, IU Office of Engagement, Price Waterhouse Corporation, Ryan LLC, BlueCross Blue Shield, CitiGroup, Allstate, and the SoapySoap Company. 2014 graduates *Kylee Miller* and *Elizabeth Szymanski* now work at Epic Systems with the title *Problem Solver*, which describes all of our graduates perfectly!

Our undergraduates have, once again, earned some of the nation's highest academic accolades.

Gates Fellowship

Indiana University Mathematics graduate, *John Brown* (2012), received the prestigious Cambridge Gates Scholarship. Quoting this International Scholarship website, Gates Scholars "have already done extraordinary things around the

World." They are "trusted with going forward and making sure this world is a better place." Like most great mathematics students, John has broad interests. An exceptional cellist as well as a gifted writer, John also earned the English Department's best graduating senior award.

John studies Dynamical Systems and Geometry at Churchill College at the University of Cambridge.

Hertz Fellowship

William Yu (2009) received the Hertz Graduate Fellowship and presently studies in the graduate Computational Biology program at MIT, where he applies sophisticated mathematical tools to answer biological questions. The first IU graduate ever to win the prestigious Hertz Award, William has a long list of other prestigious awards on his vita, including the Marshall and Goldwater Scholarships awarded during his undergraduate years of study. IU President Michael McRobbie said "William's outstanding skills in the sciences, which earned him top awards in chemistry and math while at IU, are complemented by his love for the arts and humanities, particularly music and language." While at IU, William actively participated in the swing dance club, sang in an *a capella* group, and worked on the literary magazine, *Labyrinth*.

Churchill Scholarship

Kent Griffith (2013), a Math minor and Chemistry major, received one of only 14 Churchill Scholarships awarded in 2013. He spent last year at the University of Cambridge studying graduate Chemistry.

Goldwater Scholars

Each year, the Goldwater Foundation awards just 300 scholarships nationally from a broad spectrum of fields in Science, Mathematics, and Engineering. During the past few years IU Mathematics majors have continued to earn a significant share of these awards at IU.

Mathematics majors who received the Goldwater Scholarship:

Benjamin Seitzman (2014) studies Mathematics and Neuroscience. He presented his Neuroscience research at a conference in Italy this past summer. Ben entered Neuroscience graduate school this year at Washington University, St. Louis.

Jordan Venderley (2014) took our graduate Topology course, as well as a number of graduate Physics courses. Ben began theoretical physics graduate studies this year at Cornell.

Miles Edwards (2013) studies Music Performance (cello) and Mathematics. Miles began his IU studies in our our most advanced undergraduate courses, our senior level honors curriculum. That same freshman year, Miles scored 16th nationally on the challenging William Lowell Putnam Competition. Miles currently studies graduate mathematics at the University of Chicago.

We have a Math minor among this years Goldwater scholars.

Radhika Agarwal: A senior at IU, she studies Biology and Biochemistry, working toward a research career.

Additionally, Mathematics major *Najja Marshall*, who graduated in 2014, received an Honorable Mention in 2012. Najja has begun graduate studies in Neuroscience at Columbia University.

National Science Foundation Graduate Fellowship

Robert Hawkins (2014) is among this year's National Science Foundation awardees. Only 2000 Fellowships are awarded to the more than 14000 applications from the country's most elite undergraduate students. These students enter graduate programs to prepare for a research career in math and the sciences.

Robert continues his studies in Neurobiology at Stanford, where he hopes to invest his growing mathematics skills.

Indiana College Mathematics Competition (ICMC)

IU ICMC Team, *Tom Dauer*, *Jonathan Hawkins*, and *Max Zhou*

The IU Mathematics Department continues to dominate the Indiana College Mathematics Competition, having taken first place 4 of the past 5 years. IU did not enter a team in 2013. We must give others a chance!

The ICMC, sponsored by the Mathematical Association of America, involves three-student teams that work together to solve and write a small handful of hard problems in 2 hours.

2014 winning team: *Tom Dauer* (junior), *Jonathan Hawkins* (senior), and *Max Zhou* (junior).

2012 winning team: *John Brown*, *Miles Edwards*, and *Timothy Zakian* (senior).

For those yearning for a challenge, we offer this problem from the ICMC 2014 exam.

Problem: Determine whether the following sum of real cube roots is ratio-

nal or irrational.

$$\sqrt[3]{6+\sqrt{\frac{847}{27}}}+\sqrt[3]{6-\sqrt{\frac{847}{27}}}$$

In addition to participating on the 2012 winning ICMC team for Indiana University, *Tim Zakian* spent the summer of 2012-13 interning for Cray Incorporated, a leading supercomputer manufacturer.

Research Experiences for Undergraduate awardees

Research Experiences for Undergraduate programs (REU) allow top rate graduate school bound students to experience mathematical research by working on open research problems under the guidance of attentive faculty.

Lea Beneish (senior), *Arianna Cappon* (junior), *Tom Dauer*, *Ben Seitzman*, and *Max Zhou* (junior) have participated in REU programs in various universities in recent years.

Lea Beneish

In addition to participating at REU programs at Emery and Cal State Bernardino, Lea spent this past summer at the Institute for Advanced Study in Princeton at a workshop on supersymmetry. Lea has already written two research papers titled *Structure groups of algebraic curvature tensors in dimension three* and *Two kinds of Frobenius problems in* $\mathbb{Z}[\sqrt{m}]$.

The Actuary Club

The IU Mathematics Actuary Club has grown productively in large part due to student leadership. In Fall 2013, Actuary Club President *Brad Hipsher* (2014) led weekly study sessions. He and Actuary Club Vice President *Haochi Si* (2013) taught term-long classes for exams P/1 and FM/2. They arranged both virtual and on-site visits with employers, and regularly disseminated a variety of useful information to students interested in actuarial science.

Over the past couple of years, Brad and Haochi, together with past VPs *Bo Xie* (2013) and *Hugo Sancen* (2013), designed an incredible website, `http://www.indiana.edu/~actuaria/index.html`, and also a Facebook page, `https://www.facebook.com/IndianaUniversityActuaryClub?fref=ts`. At year's end, Brad passed his knowledge and experience concerning policies and initiatives to the next generation of Club leadership.

Our Actuary Club looks forward to continued success through the energy of newly elected officers, President *Neelan Scheumann* (senior) and Vice Presidents *Cheng Shi* (junior) and *Joel Brauchla* (senior).

Faculty News

Chair Kevin Zumbrun returns to faculty life

Kevin Zumbrun ably led the Department of Mathematics as Chair for five years, from the summer of 2009 to the summer of 2014. Many exciting things happened in the department during those five years, most notably, three of our faculty, Michael Larsen, Nets Katz, and Roger Temam, were awarded the rank of IU Distinguished Professor. This is the most prestigious academic rank at Indiana University, and these appointments are not just a testament to our outstanding faculty, but also to the Chair who prepared the extensive nominations required. Prior to Kevin's term we had a distinguished faculty, but no Distinguished Professors, so this indicates the thanks the department owes to Kevin.

Under Kevin's leadership, the department has undergone several structural changes. By negotiating, eliminating inefficiencies, and restructuring, the department has increased the number of half-year fellowships for first year graduate students from five to twenty-five. This will aid the department in attracting the best and brightest students from around the world for our Ph.D. program. Most of our entering 2014 class have a fellowship. We have also increased the size of our prestigious Zorn postdoctoral fellowship program from 6 to 9 mathematicians. The Zorn fellowships enable fresh Ph.D.s to come to Bloomington for three years, and have their research and teaching mentored by our senior faculty. This is a great way to both help young mathematicians and to provide fresh ideas (and faces) for the department. The program was named for our former colleague, Max Zorn, famous for Zorn's Lemma (`http://en.wikipedia.org/wiki/Zorn's_lemma`.)

Moving on to the faculty, a new

benefit has been added; the department now grants a between-sabbatical course release to enable and encourage mathematical research. Finally, the department has been authorized to fill a new named professorship, the Charlotte Ann Griffin Professorship. This is funded by Charlotte and James Griffin, who earlier funded the William H. Boucher Professorship, currently held by the notable mathematician Vladimir Toureav.

Kevin also made a long-lasting change to the math department by leveraging his love of great coffee and supplying the department with its own expresso machine! After all, to quote the great mathematician Alfréd Rényi, "a mathematician is a machine for turning coffee into theorems."

Kevin is taking a well-deserved sabbatical in the academic year 2014-2015, being one of two mathematicians awarded the Chaire d'Excellence at the Sorbonne in Paris.

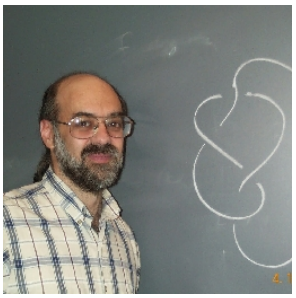
Recent accomplishments of the faculty

We next discuss a few of the awards and achievements received by our faculty since the previous issue of the alumni newsletter. For details and more information see the news section of the department's webpage: http://www.math.indiana.edu/newsevents/ Here goes. The American Mathematical Society recently instituted the AMS Fellows program to honor outstanding contributors to mathematics. Ten of our faculty members have been named AMS Fellows: Professors Eric Bedford, Hari Bercovici, David Fisher, Robert Glassey, Michael Larsen, Russell Lyons, Peter Sternberg, Roger M. Temam, Shouhong Wang, and Kevin Zumbrun. Roger Temam, was, in addition, elected an American Association for the Advancement of Science Fellow. Netz Katz, now a Professor at CalTech received a prestigious Guggenheim fellowship during his time at Indiana University. David Fisher and Michael Larsen were named Simons Fellows in Mathematics. By the way, this was funded by the Simons Foundation, named for Jim Simons, who received his Ph.D. in mathematics at the age of 23, later became the Chair of the Mathematics Department at Stony Brook, and still later resigned his position to become the founder and CEO of one of the most successful hedge fund companies. He is currently in the Forbes list of one of the top 100 wealthiest individuals in the world, and one of his many philanthropic causes is to support mathematical research!

Michael Larsen

Professor Michael Larsen recently received the Moore Research Article Prize from the AMS for his article (joint with Richard Pink), "Finite subgroups of algebraic groups." Larsen and Pink use concepts from algebraic geometry to give a classification of finite simple linear groups and thereby provide a revolutionary and influential point of view on a subject of classical interest.

Chuck Livingston

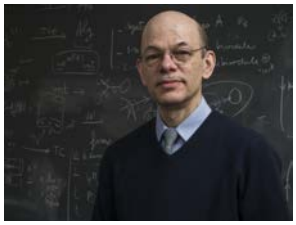


Professor Charles Livingston received the 2013 Mathematical Association of America's Indiana Distinguished Teacher Award. He was nominated by Jim Davis and Paul Kirk, and in the nomination letter, Kevin Zumbrun said of Chuck Livingston: "He is a superb teacher and scholar who seamlessly integrates instruction with his craft, and takes interest in all aspects of teaching and exploration of his field."

Marlies Gerber

Professor Marlies Gerber was a co-Principal Investigator for an S-STEM grant from the National Science Foundation. Here S-STEM is an acronym for Scholarships in Science, Technology, Engineering and Math. The grant provides undergraduate scholarships in a wide variety of disciplines: astronomy, biology, chemistry, physics, and, of course, mathematics over the next five years. Quoting IUB Provost Lauren Robel, "This program advances a number of the initiatives within our strategic planning process, including undergraduate STEM education, student diversity and innovative residential programs. It will emphasize a strong peer support system for students through a community of scholars who will be emphasizing collaboration and teamwork."

Vladimir Touraev



Professor Vladimir Touraev is our first named professor. He was recently awarded a megagrant, over $2.7 million to establish a new mathematics laboratory in Chelyabinsk, Russia. Touraev will continue in his role as the William H. Boucher Professor of Mathematics at IU, spending summers in Russia.

The award – one of 42 megagrants awarded by the Russian government this year to scientists from around the world to conduct research in the country – will allow a recognized leader in the field of low-dimensional topology to establish a scientific center based in Chelyabinsk, Russia. The new center will include about 20 students and an equal number of experienced mathematicians.

"The aim of the megagrant is to encourage the development of modern mathematics in Russia: I bring the expertise, they bring the resources and, most importantly, the students and scientists," Touraev said. "The grant will support these undergrads, grad students, postdocs and experienced mathematicians financially as a complement to their basic salaries and stipends from their home institutions, while also supporting their travel, workshops, conferences and invitations to foreign specialists."

The department is delighted that Touraev's excellence is being recognized at this scale and excited about the possibilities this raises for new international collaboration at a number of different levels: undergraduate, graduate, postdoctoral and faculty.

Touraev's expertise is in low-dimensional topology, a branch of topology – the study of the properties of geometric shapes that are unaltered by elastic distortions – that looks at two-, three- and four-dimensional structures such as knots, braids, tangles, links, surfaces and manifolds. Generally, wherever research involves continuity, equilibria, stability or dynamics, topology comes into play. Areas of modern theoretical physics like string theory, improvements in complex networks like neuron interactions and social networks, and movement planning in automated robots are all areas where topology is relevant.

"While I will try to promote some directions close to my work, I expect the established researchers to pursue their own lines of research," he said. "Quantum topology has many aspects including connections with low-dimensional topology, representations of algebras, category theory, mathematical physics. Let us just say that at this stage, the grant creates considerable opportunities for mathematicians working in these fields and excellent possibilities for collaboration."

Madan Puri

Emeritus Professor Madan Puri added to his long list of honors and awards by receiving the Samuel S. Wilks Award from the American Statistical Association, presented in August, 2014. This is one of the ASA most prestigious awards. A sampling of Professor Puri's previous honors include: the Gottfried E. Noether Award from the ASA, the College of Arts and Sciences Distinguished Research Scholar, a Humboldt Preis, the publication of three Festschrifts in his honor, and the publication of three volumes of his collected works. Professor Puri is spending this Fall as a distinguished visiting faculty member at Columbia.

Russ Lyons

Professor Russ Lyons has been invited to give a 45-minute lecture at the International Congress of Mathematicians to be held in Seoul, Korea in August 2014 in the Probability and Statistics section. This international body meets only once every four years under the auspices of the International Mathematical Union (IMU). Four of the top prizes in mathematics - The Fields Medals, the Nevanlinna Prize, the Gauss Prize, and the Chern Medal - are awarded during the opening ceremony on the first day of the congress. Professor Lyons joins Professor Emeritus Eric Bedford, Professor Sergey Pinchuk, William Boucher Professor Vladimir Touraev, and Charlotte Ann Griffin Professor Alexander Volberg as one of our faculty members chosen for this singular honor.

Professor Lyons will talk about his work in the area of determinantal probability. This area of mathematics began in physics and has recently been proposed for many uses in machine learning as a good way to sample diverse elements from a set. A probability measure is called

"determinantal" if certain probabilities have certain simple expressions via determinants. One of the first places this arose was for the eigenvalues of random matrices. It might not be surprising that determinants would arise in such a context. A completely different place it arises is in studying random spanning trees of graphs. Yet another place is in the zeroes of random analytic functions on the complex plane. Professor Lyons discovered that, in the discrete context, the random elements chosen by a determinantal probability measure always have a certain completeness property, analogous to that of a basis in linear algebra. This turns out to have powerful consequences in surprisingly different ways. Professor Lyons will talk about this and a conjectured analogue in the continuous context, and the consequences that it would have.

Roger Temam

Professor Roger Temam, College Professor of Mathematics, was promoted to the rank of Distinguished Professor. The distinguished professorship recognizes faculty who have pioneered or substantially transformed their field, garnering international recognition for their work. Professor Temam is a prolific researcher with over 350 publications and 112 Ph.D. students to date. Described as "among the five best and most influential applied mathematicians alive today," Temam's work spans many large areas of applied mathematics, including numerical computation of fluid flows, slow dynamics and inertial manifolds, turbulence theory, and climate modeling.

Elizabeth Housworth

Professor Elizabeth Housworth was inducted into the Faculty Colloquium on Excellence in Teaching (FACET) in Spring, 2014, joining Professor Peter Sternberg as members from the Department of Mathematics. FACET is a community of Indiana University faculty members who are committed to being – and helping others to be – exceptional teachers.

General News

PIC Math

In addition to developing and teaching a new Careers in Mathematics course, our Director of Undergraduate Studies, Kevin Pilgrim, is participating in a summer faculty training workshop offered by the Mathematical Association of America Program: Preparation for Industrial Careers in Mathematical Sciences. Professor Pilgrim will be offering a Spring Semester course for students to work on a realistic industrial problem. By the end of the spring semester, students will submit a video presentation and written report detailing their solution for a student competition.

M119: Brief Survey of Calculus Videos

As mentioned in our last newsletter, the department has created Brief Survey of Calculus, M119, videos, similar to The Finite Show, to help students review Applied Calculus material. You can watch the crazy antics of Professor Mike Jolly, Professor Peter Sternberg, with guest appearances by Senior Lecturer Steve McKinley of the Finite Show, and selected problem solutions by graduate student participants at https://resources.oncourse.iu.edu/access/content/group/a75a6608-3698-4b62-803d-063040fce113/Public%20Materials/M119Tube_MP4.html Thanks also goes to Senior Lecturer Tracy Whelan for advice about M119, Professor Kevin Zumbrun for making it all happen, the Provost for Undergraduate Education for financial support, and IU Radio and Television Services for all of their expertise.

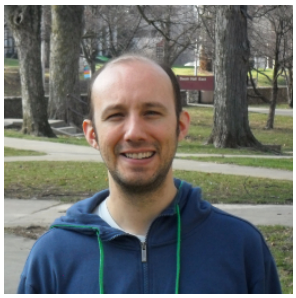
Additionally, Professor Chris Judge and graduate students Tristan Tager and Dan Lithio have been creating their own video lectures in order to flip the course by having students view lectures outside of class and use class time to help students with solving problems themselves. http://www.youtube.com/user/CinemaM119

Graduate Student Furniture

We have upgraded some graduate student offices with high efficiency furniture and beautiful new boards for discussing mathematics. Check out Swain East 030 at your convenience.

New Faculty

Noah Snyder



Noah Snyder (Ph.D. University of California - Berkeley, 2009), Assistant Professor since 2013. Noah Snyder works on quantum symmetries in Algebra, Topology, and Operator Algebras. He is especially interested in the "Galois theory" of von Neumann subfactors and in the relationship between tensor categories and topological quantum field theory.

Ajay Ramadoss

Ajay Ramadoss (Ph.D. University of Chicago, 2005), Assistant Professor since 2013. Ajay Ramadoss works in Noncommutative Geometry and Algebraic Geometry, focusing on the use of tools from Homological Algebra (in particular, Hochschild and Cyclic Homology) to study several problems in these fields. Some of these problems pertain to the study of derived moduli spaces of representations of (noncommutative) algebras.

Michael Damron

Michael Damron (Ph.D. New York University, 2009), Assistant Professor since 2013. Michael Damron's field of research is Probability Theory. His work focuses on percolation models, spin glasses and probability related to statistical mechanics.

Dylan Thurston

Dylan Thurston (Ph.D. University of California - Berkeley, 2000), Associate Professor since 2012. Dylan Thurston's research centers around low-dimensional topology and the geometric and algebraic structures within it. Particular areas of focus include Heegaard Floer homology and dynamics of rational maps.

Matt Bainbridge

Matt Bainbridge (PhD Harvard University, 2006), Assistant Professor since 2010. Matt Bainbridge's research is in Geometry and Dynamics with emphasis in Riemann surfaces, Teichmuller theory, and rational billiards. His recent work aims towards classifying polygonal billiards tables with special dynamical properties, using techniques from algebraic geometry, number theory, and conformal geometry.

Shabnam Kavousian

Shabnam Kavousian (Ph.D. Simon Fraser University, 2008), Lecturer since 2011. Shabnam Kavousian's work focuses on Mathematics Education, specifically on post secondary mathematics education and curriculum design. She is interested in studying pedagogies that involve students in the classroom and motivate them outside of the classroom. Shabnam's mathematical passion is Combinatorics and Graph Theory, particularly graph coloring and graphs homomorphisms.

Palanivel Manoharan

Palanivel Manoharan (Ph.D. Ohio State University, 1990), Lecturer since 2010. After spending 12 years in administrative positions, Mano, as he prefers to be called, wanted to get back to teaching which he loves and accepted a posi-

tion at IU in 2010. His interests are Topology and Geometry. Before coming to IU, he taught at Ohio State, Kent State, University of Maryland University College and Penn State.

Retirements

Allan Edmonds

Allan Edmonds was born in Bartlesville, Oklahoma, on November 4, 1946. He received his B.S. degree from Oklahoma State University in 1969 and his Ph.D. from the University of Michigan in 1973. After a year at the Institute for Advanced Study in Princeton, he became an assistant professor at Cornell University. In 1978 he accepted an appointment as Associate Professor with tenure in the Indiana University Department of Mathematics, and was promoted to full professor in 1983.

Much of mathematics is devoted to the study of symmetry, from the simple structure of Platonic solids to the complex repetitive patterns that appear in decorative arts. Within the field of topology, symmetry is explored in the realm of "transformation groups." It is in this realm that Allan has published many of his more than 60 research articles, beginning with his earliest work and continuing to some of his most recent articles.

Although mathematicians study symmetry from the perspective of many dimensions, some of Edmond's most important work has focused on classical two-dimensional theory. One of his most beautiful accomplishments was the solution of a problem with formal roots dating to the 1880s, asking for a generalization of Euclid's mathematical investigations of the five Platonic solids. Allan, working with IU colleagues John Ewing and Ravi Kulkarni, Allan achieved the long sought generalization of Euclid's theorem. This work appeared in the most prestigious journal, the Annals of Mathematics.

Allan's research extends into several other realms, including the study of the basic topological and algebraic properties of low-dimensional spaces. In recent years Allan has developed another area of expertise, investigating high-dimensional generalizations of classical results from Euclidean geometry.

Allan's contribution to research mathematics goes well beyond his publication record. In his mastery of fundamentals, his clarity of thought and presentation, and his generosity as a colleague, he has served as a superb mentor and role model for his graduate students and colleagues.

Throughout his career, Allan has approached his teaching with an unusual combination of professionalism and creativity, carried on at every level and over the full range of the mathematics curriculum, from freshman courses on finite mathematics and calculus, to advanced graduate courses on topology. His leadership has been apparent in his early and enthusiastic inclusion of computer and Internet-based tools in the classroom. A particular area in which Allan has been especially influential is in teaching courses for prospective secondary mathematics teachers, courses in which he maintained the highest expectations of rigor and precision combined with a shared sense of enthusiasm and joy about mathematics – all of this driven by a clear sense of the importance of preparing these future educators.

Allan has accepted, and often sought out, many of the most challenging service roles in the mathematics department, including those of chair and director of graduate studies. In fact, there are few committees on which Allan has not served. In every setting his work has been marked by unusual care and professionalism. Too numerous to enumerate, the list includes his shared work with Darrell Haile in leading the department to a highly prestigious NSF Vertical Integration of Research and Education (VIGRE) grant, which for years brought to IU many top-notch postdoctoral fellows and excellent graduate students. Another of Allan's notable contributions has been to the IU Advance College Project, in which he has helped select and mentor high school mathematics teachers throughout Indiana who teach courses in their schools for IU credit. Allan also led the IUB NSF funded REU program (Research Experiences for Undergraduates), bringing top undergraduates to Bloomington for summer study.

Extending his contributions to the College and university, Allan served on numerous committees, including tenure and promotion committees, the College Policy Committee, and a search committee for the Dean of the College. Again demonstrating his commitment to our educational mission, he has served on the College Committee on Undergraduate Education and has long

been a mainstay on joint committees with the School of Education.

Allan's contributions extend well beyond the university. Of special note: his younger daughter Becky's participation in her school's Gifted and Talented Program led Allan to his service over the years on the school district's MCCSC Advisory Committee for the Gifted and Talented Program. Inspired by his daughter Katie's participation the Bloomington South Solar Bike Team, Allan transformed from being a commuting cyclist to an avid bike rider, and he has served several terms as the President of the Bloomington Bicycle Club. Allan and his wife Ann are early adopters of solar energy; their house is now almost electrically self-sufficient.

Everyone in the department looks forward to Allan's continuing presence in our department.

by CHARLES LIVINGSTON

Eric Bedford

Eric Bedford was born on December 23, 1947. He received his B.A. from the University of Illinois in 1969, and then went on to the University of Michigan, where he received his Ph.D. under Al Taylor in 1974.

Eric worked as an Instructor at the Courant Institute, New York University, from 1974 to 1976, and as an Assistant Professor at Princeton University from 1976 to 1982. Eric joined Indiana University in 1982 as an Associate Professor with Tenure, and was promoted to full professor in 1985. Eric also has held numerous visiting positions. Eric has made major contributions to the field of several complex variables. In particuar, he obtained a number of remarkable results concerning holomorphic envelopes of real hypersurfaces, construction of peak plurisubharmonic functions for weakly pseudoconvex domains, boundary regularity of biholomorphic mappings, and domains with noncompact automorphism groups.

In the 1970's and 1980's Eric and Al Taylor developed their fundamental work on the complex Monge-Ampère operator and revolutionalized pluripotential theory, the study of plurisubharmonic functions. They showed that this second order, nonlinear differential operator has a natural extension to the space of locally bounded plurisubharmonic functions, and they solved an associated Dirichlet problem on strictly pseudoconvex domains. Utilizing this work, they essentially "linearlized" the nonlinear potential theory associated with this operator. In particular, they utilized their notion of relative capacity to give insightful and elegant solutions of two problems of Lelong on pluripolar and negligible sets. Today their techniques and results are used in variational and viscosity approaches to complex Monge-Ampère type equations arising in complex geometry; e.g., on compact Kähler manifolds, as well as in multidimensional complex dynamics.

In the late 1980's, Eric turned his attention to the study of dynamics in several complex variables. Between 1991 and 2006, he wrote a series of major papers, co-authored with John Smillie. Their application of pluripotential theory to the study of polynomial diffeomorphisms of $\mathbb{C}^2$ and $\mathbb{R}^2$ led to fundamental progress in the understanding of the dynamics of the famous Hénon maps. More recent collaboration with Jeff Diller and Kyounghee Kim focused on the challenging problem of the description of the global dynamics of birational, but not necessarily holomorphic, self-maps of complex surfaces. This work led to the discovery of rational surface automorphisms with rotation domains, and gave a rigorous treatment of topics previously investigated empirically by physicists.

Eric has published over 110 papers, highly cited in the field (about 1300 citations, according to MathSciNet). He has received continuous research support from the National Science Foundation since 1974. He has been a member of editorial boards of such journals as the Indiana University Mathematics Journal (1974–present), Proceedings of the American Mathematical Society (1993–2006), and Journal of Geometric Analysis (1986–2011).

Eric is an excellent expositor. He has given a number of talks at national and international conferences. In 1990 he was an invited speaker at the International Congress of Mathematicians in Kyoto. Eric has worked very closely with several post-doctoral fellows and visitors, and he continues to work actively with graduate students. Two of his students, Turgay Bayraktar and Tuyen Truong, are expected to defend their theses by the end of Spring 2012. Eric is an excellent colleague, deeply involved in departmental affairs and always ready to help others in resolving difficult situations.

Eric is widely known for his wonderful hospitality, opening his home to seminar attendees and depart-

mental visitors of all ilks. Drinking a glass (or bottle) of good wine is obligatory chez Eric. He is a reliable, caring friend, appearing on your doorstep with unexpected presents at random times. He has a great sense of humor; indeed, several years ago at a conference party at the old Banach Center in Warsaw, Eric won the "best joke" competition hands down. Ask him for one – and you'll probably get a nice meal and a glass of fine Bordeaux red with it!

by THOMAS BAGBY, NORMAN LEVENBERG, KEVIN PILGRIM, AND SERGEY PINCHUK

Vinay Vithal Deodhar

Vinay Deodhar was born in Bombay, India on December 3, 1948. He attended Bombay University and received his doctoral degree from there in 1974 with Madabusi Raghunathan. He was a research fellow at the Tata Institue of Fundamental Research for a year after receiving his degree and then was a visiting member at the Institute for Advanced Study in Princeton from 1975 to 1977. He returned to the Tata Institute as a Fellow from 1977 to 1982. During that time he spent a year as a Research Fellow at the Australian National University in Canberra. In 1981 he visited IU and joined the faculty the following year as an associate professor. He was awarded tenure two years later and became a full professor in 1988.

Vinay has made fundamental contributions to mathematics, particularly Lie theory. While still a student he wrote up a highly influential set of notes based on lectures by Robert Steinberg. In 1978 he was awarded the Young Scientist Award from the Indian National Academy. Vinay is one of the developers of Kazhdan-Lusztig theory (and in fact he coined the term) and has done important work on the geometry of flag varieties. In 1992 he edited a volume of the AMS series Contemporary Mathematics on the subject. He also has made important contributions to the theory of Bruhat orderings on Coxeter groups.

Vinay has always shown a great commitment to teaching. He is a very popular and successful teacher, particularly in the department's honors undergraduate courses and at the graduate level, and is known for the clarity of his lectures. In 1998 he earned our highest teaching award, the Rothrock award. He has also been active in our mentoring program and has helped many of our postdoctoral faculty to become better instructors. He was in fact head of the program for several years during the time the department was involved in the VIGRE program. He was also director of graduate studies from 1990 to 1992.

Vinay is greatly devoted to his family; his wife Vineeta and his two children, Abhijit and Aditi, both of whom have been students here at IU. In the last several years he has shown exceptional courage dealing with illness while still continuing his distinguished teaching and mentoring.

by DARRELL HAILE

Scott Brown

Scott Brown was born in Chicago, Illinois, in 1948. He received his B.S from University of California, Riverside in 1970. He received his PhD from University of California, Santa Barbara in 1978 under the direction of John Ernest, with dissertation: Banach Algebras that are Dual Spaces. After graduation, Scott took an American Math. Society Research Fellowship for one year, then joined the faculty of University of Hawaii as an Assistant Professor, staying from 1980–1984.

After an NSF Research Fellowship/Visiting Assistant Professorship at University of California, Berkeley from 1984-1986, and a Visiting Associate Professorship at University of Michigan from 1986-1988, Scott joined Indiana University as an Associate Professor, where he has stayed ever since as a familiar figure in the departments distinguished group in Operator Theory. He served as Director of Graduate Studies from 2002-2003, and has been a mainstay of the Personnel, Salary, and other advisory committees of the department for many years.

Much of Scott Brown's mathematical work is concerned with the existence of invariant subspaces of linear operators on a Hilbert space. These linear operators are infinite dimensional analogues of finite matrices, and invariant subspaces ease their study by decomposing them into smaller blocks. Scott discovered completely new and unexpected ways of proving the ex-

istence of invariant subspaces. This gave rise to what is now known as the Scott Brown technique, and its importance was recognized in 1991 by its inclusion, under the name dual algebras, in the Mathematics Subject Classification index (where it can be found as 47L45). The first appearance of this technique is in Scott's thesis. One of the main results there, published in 1978, is the existence of invariant subspaces for subnormal operators. This resolved a long-standing problem, posed by Paul Halmos when he was on the faculty of our Mathematics Department. This result was quickly developed by Scott and others to much more general classes of operators, characterized by norm and spectral properties alone. One peak of this research was reached in a 1988 paper by Scott where yet another component of the Scott Brown technique was put in place. Almost immediately, this led Scott, along with Bernard Chevreau and Carl Pearcy, to show that contractions with spectral boundary have invariant subspaces. Progress in a different direction was made in Scott's 1987 paper in the *Annals of Mathematics*, where he considers hyponormal operators with sufficiently large spectra. This result also led to further developments at the hands of many contributors. Significant contributions to the techniques developed by Scott were made by his his students Julian Sheung and Eungil Ko.

To explain briefly what the Scott Brown method entails, we will provide a brief mathematical sketch. Finding a (nontrivial) invariant subspace for an operator T amounts to finding vectors x, y, different from zero, such that all the scalar products $< T^n x, y >$ vanish. This condition can be written more succinctly as $x \otimes y = 0$, where the product $x \otimes y$ of two vectors is viewed as a linear functional on polynomials in one variable. In other words, one is looking for a factorization of the zero functional as a product of two *nonzero* elements. Factorizations of some other functionals f as $f = x \otimes y$ yields invariant sub-spaces and, provided that $f \neq 0$, the vectors x, y cannot be zero; this leads to nontrivial invariant subspaces. Scott's idea was to focus on the equation $x \otimes y = f$, and show that it can be solved for every given f. Once this is done, the invariant subspaces, along with much additional information, follow easily. The techniques for achieving this universal factorization start with an argument reminiscent of the open mapping theorem (in Scott's thesis), and continue with many refinements including the striking argument from his 1988 paper which reveals an unexpected fact in measure theory. Yet other techniques are required in Scott's treatment of hyponormal operators.

Unlike older results on invariant subspaces, which tend to be of very limited usefulness, the techniques developed by Scott Brown have proved to be very versatile, and their full impact has not yet been realized. Several of his results will become textbook material, and some of them have already made it into several monographs on operator theory.

by HARI BERCOVICI

David C. Hoff

David Hoff was born in Detroit, Michigan, in 1948. He received a B.S. in Physics (1970) and a M.S. in Mathematics (1972) from University of Michigan. He received his Ph.D. in Mathematics (1977) from University of Michigan under the direction of Joel Smoller, with dissertation: Stability and Convergence of Finite Difference Methods for Systems of Nonlinear Reaction-Diffusion Equations.

After a year spent as visiting member at the Courant Institute of Mathematical Sciences in 1977-1978, David joined Indiana University as Vaclav Hlavaty Assistant Professor in 1978. He has remained here as a central figure in the Mathematics Department and the Applied Mathematics/Partial Differential Equations group for the following 34 years, from 1978-present. David was promoted to Associate Professor in 1984 and to Full Professor in 1989. He served as Director of Graduate Studies from 1986-1988 and Chairman of the department from 2003-2006, and has continued to guide the department through his wise counsel in the following years. He has been a mainstay of qualifying and other departmental exams for many years.

Likewise, David has been a central figure in his field of nonlinear partial differential equations (PDE). The main object of his research has been to study global existence and asymptotic behavior for solutions to a variety of nonlinear evolution equations arising in physi-

cal applications, such as the Navier-Stokes equations of compressible fluid dynamics, magnetohydrodynamics, and combustion theory, and Reaction Diffusion equations ubiquitous in pattern formation, population dynamics, chemical reactions, and more.

David has published over 74 papers, highly cited in the field (over 1,103 citations by 481 authors, according to MathSciNet) and quite influential. For example, his paper Large time behavior of solutions of systems of nonlinear reaction-diffusion equations, with Conway and Smoller [SIAM J. Appl. Math. 1978] can be regarded as an initial prototype for the rich field of attractor theory in dissipative partial differential equations. His paper Global solutions of the Navier-Stokes equations for multidimensional compressible flow with discontinous initial data, [JDE, 1995], together with a simultaneous work by Fields medalist Pierre-Louis Lions, was a tremendous breakthrough, setting off a whole industry of existence theory for rough data that continues in full activity to this day. His work in general is marked by its innovation, technical difficulty, and depth of thought.

David has held visiting positions at University of Michigan in 1983-1984 and 1999-2000. An excellent expositor, he is a sought-after speaker in his field, attending numerous national and international conferences. David received continuous research support from the National Science Foundation for 31 years, during the period 1979-2011.

David is known as an extraordinarily clear and inspiring instructor, beloved by several generations of students. Indeed, his expertise has been recognized by a number of teaching awards: he won the University President's Award in Teaching in 1996, the Trustees teaching awards in 1997 and 1999, and the Rothrock Teaching Award in 2008. He has guided 8 students to PhDs, most of whom are now professors of Mathematics themselves.

In his spare time, David is an avid runner, pianist, and gardener. With wife Nancy, he travels frequently to visit children Peter, Tom and Mary, and grandchildren. An accomplished raconteur, David has entertained his colleagues at tea time over the last decade with his uncannily consistent predictions of presidential election results, as well as nourished them with post-election donations of fruit.

David has made tremendous contributions to the Department of Mathematics, and the individuals who have passed through it over the years; we hope that he will continue in his retirement to grace us with his wisdom, humor, and lively discussions mathematical and otherwise.

by KEVIN ZUMBRUN

Darrell Haile

Darrell Haile retires this year after 36 years of service in the IU Department of Mathematics. Darrell joined the department in 1978 as an assistant professor after a postdoctoral appointment at SUNY Buffalo and an instructorship at Northwestern. He earned his Ph.D from Yale in 1977 under the distinguished algebraist Tsuneo Tamagawa. His undergraduate degree came from Franklin and Marshall College in 1970. During the years after coming to Bloomington he rose through the ranks to full professor and played a quietly effective role in the life of the department.

Within the department his service included a term as director of undergraduate studies. He was a co-PI on a major National Science Foundation VIGRE training grant that helped to reshape and mold the department as it configured itself for the 21st century.

For many years he actively participated as co-chair with Dan Maki and as a faculty advisor in the department's Research Experiences for Undergraduates program, and was co-PI on the NSF grant funding the program. He himself was a participant in the URRP program, the forerunner of the REU program, during the summer of 1969 here at IU.

Within the university two service activities stand out: a term on the College of Arts and Sciences Policy Committee and a term as president of the local chapter of Phi Beta Kappa.

In service to the profession Darrell held a five-year term as book review editor for the American Mathematical Monthly, the world's premier journal of collegiate mathematics.

Darrell's research has focused on the study of non-commutative algebra, a version of algebra in which the order of multiplication can actually make a difference. The familiar case of n by n matrices is the first example most math students encounter of this phenomenon. He brought new life to the study of Clifford algebras, connecting this classical nineteenth century subject with modern ideas in geometry and representation theory.

Darrell is the author or co-author to date of some 34 research papers. About half of his work has

appeared in the Journal of Algebra, the leading journal in his field. Much of his research was supported by grants from the National Science Foundation. Unlike most mathematicians, whose pace of research tends to slow with age, he has, if anything, accelerated his tempo in recent years. He remains engaged in joint projects with mathematicians in Belgium, Taiwan, Israel, and throughout the United States.

Darrell has been unusually successful as a Ph. D. supervisor. His former students hold positions at research universities throughout the world: in East Asia, South Asia, the Middle East, even the South Pacific, and of course, in this country. All but one, who now works on cryptography for the U.S. government, have found academic employment, a difficult task in recent years. His last two students finished their degrees in 2013.

Darrell has always had a masterful teaching style. In the old days, he would typically enter the classroom without notes, slam his key ring on the desk, and proceed to lecture, discussing the subject at hand from memory. Most recently he reports that he has eliminated the step of depositing his keys on the lectern. But those keys remain a happy memory for many in Bloomington.

After leaving Yale but before finishing his thesis, Darrell spent two years as an instructor at Northwestern University. During that time his well-worn copy of Jean-Pierre Serre's classic monograph Corps Locaux was falling apart, and he resolved to re-bind it himself. With that in mind, he audited an evening book-binding course held at the Learning Resource Center in Chicago. It was there that he first met his future spouse Annette Alpert, then an advanced graduate student in Russian Studies at the University of Chicago. She still vividly remembers the large set of keys he deposited on the desk each week!

Together the new couple moved briefly to SUNY at Buffalo where Darrell had a position as an assistant professor and Annette reconsidered her status as an ABD in Russian Studies. In 1978 the pair moved to Bloomington, where, except for brief leaves, they have been ever since. During his early years in Bloomington, Annette changed course, embarking on the pursuit of a medical degree. Medical school led to some periods of separation during her years in Indianapolis and to temporary positions for Darrell in Chicago during Annette's residency. Darrell and Annette together negotiated those early years of intense study and work with aplomb.

The couple has an adult son, Benjamin, who lives in Bloomington and plans soon to work toward a career as emergency medical technician or EMT.

Darrell and Annette (now a retired Bloomington cardiologist) own a familiar classic limestone house in the historic district in Elm Heights, where they serve, in Annette's words, as "caretakers." They have a weekend getaway cabin in Owen County, which has provided a welcome respite from Annette's many hours on call. They recently purchased an apartment in Israel, a country to which they are both deeply committed. They hope eventually to spend half the year there, enjoying the beautiful Israeli weather as well as Darrell's ongoing research collaborations with mathematicians in Haifa and Tel Aviv.

by ALLAN EDMONDS AND MICHAEL LARSEN

Greg Peters

Guy (Greg) Peters received a B.S. degree from Wayne State University in 1964 and an A.M. degree from the University of Michigan in 1967. In 1968, Greg moved from Michigan to Bloomington Indiana, where he began teaching mathematics at the Indiana University Laboratory School, known as University High. Since that time, Greg has been an enthusiastic, dedicated, and successful advocate for good mathematics teaching. His long and successful career has included teaching mathematics at high schools and at Indiana University and helping to guide and mentor mathematics teachers all over the state of Indiana. He has also played a key role in the smooth operation of the mathematics department at IUB. His many accomplishments and the key roles he has played are summarized below.

After the closing of University High School, Greg moved to the new Bloomington High School North (BHSN), where he quickly became known as an outstanding mathematics teacher. At this time he also began summer teaching for the IUB mathematics department and became a regular summer calculus teacher on campus. His success at teaching at BHSN and at IU, together with the needs of the mathematics department at IUB, resulted in the department creating a position especially for him in 1986. Since that time he has been a key player in the long-term success of the department and in serving as a department liaison to

high schools around Indiana.

At the time that Greg joined the mathematics department at Indiana University, the department very much needed someone to do the scheduling of the many classes needed each semester, to do some teaching, and to also serve as a liaison to high school mathematics departments. Greg had already taught for the department in the summers, so he was well-known to many in the department. It took very little time for Greg to show that he was a wonderful resource for our department. Since 1986, he has played many roles in the department, and the words consistently used about him are ones such as: irreplaceable, indefatigable, and, most importantly, always happy and willing to help out. These qualities describe Greg Peters, yet he has meant much more to the mathematics department than these words convey.

First, regarding teaching, Greg has taught 100 and 200 level courses for us and has often offered a seminar on the teaching of undergraduate mathematics for our new graduate students. He has always been highly regarded as a teacher, and students always sought to be in his classes.

For many years now, Greg has had the enormous job of scheduling all mathematics department classes (including room and faculty assignments) and of keeping track of constantly changing enrollments. This is particularly challenging at the beginning of each semester because of our huge enrollments. He always managed to cover our teaching loads while deftly dealing with faculty egos and their teaching preferences.

At the same time as he was doing his own teaching and the scheduling for the department, it was often the case that when faculty had to be away during the semester (e.g., for planned short visits to take part in conferences, or for unplanned events such as family emergencies), Greg would volunteer to teach their low level courses. He often did this several times a semester and was the department's strong relief pitcher.

To illustrate his many extra services for the department, during weekends of the academic year when the very large Departmental M118 and M119 exams are given, Greg has always been there with doughnuts and coffee (even if he was not teaching one of these courses) to make sure all went well. Greg could also be relied upon to answer student and staff questions when regular faculty/advisors are not available, and he does so eagerly often following up with the student to be sure they are helped.

Greg worked very well with members of the College of Arts and Sciences administrative staff and with the registrar's office, and he was known for providing instant, straightforward, and helpful responses toward fulfilling the teaching goals of the university.

One special point to note about Greg is his work with high school teachers through the Indiana University dual credit program. During the last 30 years, Indiana University has developed this large, very successful, and highly regarded program of dual college and high school credit, called the Advance College Program (ACP). Greg Peters has played an important role in all phases of the development of ACP. ACP was started by Les Coyne, Dean of Summer Sessions and Special programs, working with faculty in the Mathematics and Chemistry Departments. The first year involved Bloomington High School South (Chemistry) and Bloomington High School North (Mathematics). Greg Peters was the mathematics teacher at BHSN and his success with the course and the program quickly helped to extend the program to many other high school mathematics departments around the state of Indiana. A few years later, when Greg officially joined the mathematics department at IUB, he moved to the university side of ACP and since then he has helped greatly in fostering and continuing the success of the program. He represented us state-wide with Indiana high schools through the ACP Program. This involved his visiting a large number of high schools as well as helping to run seminars here for high school teachers who participate in the ACP program. In this capacity he has been a wonderful ambassador for us.

Greg will be sorely missed. The many functions he performed will present a challenge for whoever follows him. In retirement he will surely often visit his son and two daughters who live in Indiana, and he will continue his love affair with athletics, both as a spectator for his two favorite teams Michigan and Indiana and as a participant. He was a very good player of both football and baseball and will certainly continue to be found on the racquetball courts where, as a tremendous semi-pro player, he will continue to dominate opponents, both young and old.

by DAN MAKI

Obituary

Jan Jaworowski

Jan Włodzimierz Jaworowski, whose gentle nature hid an indefatigable spirit, and whose research and teaching left an indelible imprint on generations of graduate students, undergraduate students, and colleagues, died from pneumonia on April 10, 2013. He was 85.

In 1964, Jan left his home in Poland, where he had established himself as a leading mathematician, to move to the United States. After academic visits to Oxford University, the Institute for Advanced Studies at Princeton, Cambridge University, and the University of Chicago, and an appointment as an Associate Professor at Cornell University, Jan arrived in Bloomington where he spent the remainder of his long and productive career, residing here for 48 years.

Jan explored extensions of the Borsuk-Ulam theorem, named for his doctoral thesis advisor and collaborator, Karol Borsuk. Jan uncovered an array deep and theoretical results, exposing the Borsuk-Ulam theorem as the first case of a broader theory.

The Borsuk-Ulam theorem supplies an elegant and easily understood example of how deep, theoretical mathematics can lead to unexpected insights regarding our physical world. This theorem states that any continuous function from a sphere to a plane must take equal value at some pair of antipodal points on the sphere. A continuous function assigns, to each point of a spherical parameterization of the Earth, the temperature and humidity at that point. One concludes from the Borsuk-Ulam theorem that at any given time some pair of antipodal points on the Earth have precisely the same temperature and humidity. One obtains this remarkable meteorological result with almost no empirical data, using only that temperature and humidity vary continuously along the Earth's surface.

Jan published 64 papers written over a span of 57 years, including 12 papers in retirement. His first paper, in the important journal *Fundamenta Mathematicae*, appeared in 1952 and his last paper appeared in 2009 in the *Journal of Fixed Point Theory and Applications*. Following Jan's retirement, mathematicians continued to visit Bloomington from around the world to learn from his insights. Jan presented elegant and polished lectures in seminars at IU and at leading research centers in many European countries, and in Korea, Taiwan, New Zealand, and Australia.

Jan Włodzimierz Jaworowski was born in Augustów, Poland, on March 2, 1928, one of 10 children. After college studies at Warsaw University, he received his Ph.D. from the Polish Academy of Sciences in 1955 under the direction of a pillar of modern mathematics, Karol Borsuk.

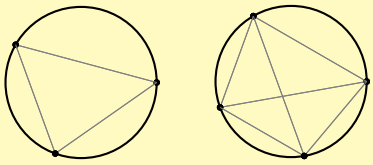
In addition to his home in Bloomington, Jan maintained a robust international presence, with a flat in Warsaw, frequent breaks for skiing in Zürich, and trips to Heidelberg, where he spoke fluent German. His visiting professorships included stays at Oxford (1957-58), Saarbrücken (1963), Heidelberg (1972, 1975, 1978-79), Auckland (1983, 1987, 1995), the University of Western Australia (1983, 1995), and the University of Munich (1982, 1985-86, 1995, 1997.)

An exemplary and well-loved teacher, Jan especially enjoyed working with graduate students. He guided 12 graduate students through a Ph.D. dissertation, and has 17 academic descendants (students, and their students.) Known to his undergraduate students as "Dr. J," he taught clearly and effectively at every level.

Problem Corner

continued from page 1

Problem 2: Draw a circle with a finite number of points on it, and connect each pair of points by a line segment. The line segments divide the area within the circle into disjoint regions. (Assume the points are arranged so that there is no triple intersection of line segments.) For instance, if we have 2, 3, 4, or 5 points on the circle, this results in 2, 4, 8, and 16 regions respectively.



Can you find a function whose value at n is the number of regions obtained by connecting n points on the circle in all possible ways? Is this function exponential? Polynomial? (Compute the $n = 6$ case. Any surprises?)

Around the Department

§ 2012 Awards §

Undergraduate Awards

These first-year students won awards and scholarships: Mary Pasquale, Jenna Pinkston, Chloe E. Urbanski and Timothy A. Zakian (Thelma Abell Prize); and Lea Beneish (Ruth E. Gilliatt Memorial Scholarship).

These second-year students won awards and scholarships: Megan E. Janke (Thelma Abell Prize); Zhichao Wang (Trula Sidwell Hardy Scholarship); Sidney F. Fletcher (Cora B. Hennel Memorial Scholarship); John Debrota and Robert D. Hawkins (Marie S. Wilcox Scholarship).

These third-year students won awards and scholarships: Kristen R. Haubold (Thelma Abell Prize); Miles D. Edwards (Ciprian Foias Prize); Jeffrey Im (Trula Sidwell Hardy Scholarship); Alec W. Davidson, Sal D. Lombardo and Lindsay J. Martin (Cora B. Hennel Memorial Scholarship).

These fourth-year students won awards and scholarships: John R. Brown II (Rainard Benton Robbins Prize); Frances E. Richert (Ruth E. Gilliatt Memorial Scholarship); Christine E. Brugger, Zachary F. Hallberg, Andrew Q. Kamerud and Robert P. Lahre (Marie S. Wilcox Scholarship).

Kyla Baldwin won the M118 Undergraduate Intern Award.

Graduate Awards

The following graduate students won awards and scholarships: Yu-Min Chung, So Yeun Jung, Neeraj Kashyap, Joshua Link, Vincent Martinez, Juanita Pinzon Caicedo, Jonathan Poelhuis, Juan-Carlos Rojas (David A. Rothrock Associate Instructor Award); Henry Horton, Hailing Hu, Ravi Joseph, and Ling Li (College of Arts and Sciences Top Up Award); Ranjan Rohatgi, Fangye Shi, and David Sprunger (Hazel King Thompson Fellowship); Hailiang Hu, Ranjan Rohatgi, and Fangye Shi (James P. Williams Memorial Award); Fangye Shi (Robert E. Weber Memorial Award); Vincent Martinez (Matias L. Ochoada Fellowship); Brett Jefferson (Adam W. Herbert Graduate Fellowship); Blake Barker and Turgay Bayraktar (College of Arts and Sciences Travel Award); Juanita Pinzon Caicedo, So Yeun Jung, and Xiaoyan Wang (Women in Science Program Travel Award); Neal Coleman, Hailiang Hu, Aimin Huang, Honghu Liu, Russell Lodge, Rafael Monteiro da Silva, Jonathan Poelhuis, Taylan Sengul, Anthony Suen, Andrew Tapay, Ihsan Topaloglu and Jinghua Yao (Glenn Schober Memorial Travel Award); Ko-Shin Chen (Muriel Adams Stahl Graduate Fellowship); Truyen Truong (College of Arts and Sciences Dissertation Year Research Fellowship); Justin Young (Outstanding Thesis Award); Tri Lai and Ihsan Topaloglu (William B. Wilcox Mathematics Award); Francesco Di Plinio (Joseph & Frances Morgan Swain Fellowship).

Faculty Awards

Paul Kirk received the Rothrock Mathematics Faculty Teaching Award. Andrew Dabrowski, Michael Jolly, Michael Larsen, and Charles Livingston won the IU Trustees' Teaching Award. James Hendrickson won the Student Choice Award.

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§ 2013 Awards §

Undergraduate Awards

These first-year students won awards and scholarships: Thomas J. Dauer (Ciprian Foias Prize); and Max S. Zhou (Trula Sidwell Hardy Scholarship).

These second-year students won awards and scholarships: Lea Beneish and Kevin Miloshoff (Thelma Abell Prize); Eva Loveland (Ruth E. Gilliatt Memorial Scholarship); Jonathan Hawkins (Cora B. Hennel Memorial Scholarship); and Timothy Zakian (Marie S. Wilcox Scholarship).

These third-year students won awards and scholarships: Robert Biggs, Xijin Cheng, and Zhichao Wang (Thelma Abell Prize); Daniel Carmody, Sanjeev Chilukuri, and Robert Hawkins (Cora B. Hennel Memorial Scholarship); and Jordan Venderley (Marie S. Wilcox Scholarship).

These fourth-year students won awards and scholarships: Miles Edwards (Rainard Benton Robbins Prize); Mak Hozo (Thelma Abell Prize); Lindsay Martin (Ruth E. Gilliatt Memorial Scholarship); Philip Thomas (Trula Sidwell Hardy Scholarship); Kevin Carlson, John DeBrota, Trevor Leslie and Ted Ofner (Marie S. Wilcox Scholarship).

Yeonjin Kim, Kate Schilling, and

Benjamin Seitzman won M118 Undergraduate Intern Awards.

Graduate Awards

The following graduate students won awards and scholarships: William Kanegis and Calvin Woo (Hazel King Thompson Fellowship); Christine Brugger, Eleanor Conley, Dami Lee, Philip Silberman, Ruiyu Yang, and Andres ZuÃśiga (College of Arts and Sciences Top Up Award); Samantha Allen (Muriel Adams Stahl Graduate Fellowship); Zachery Lindsey (Robert E. Weber Memorial Award); Justin Cyr, Zachery Lindsey, Calvin Woo, and Junyan Xu (James P. Williams Memorial Award); Raphael Clouatre (College of Arts and Sciences Travel Award); Holly Attenborough, Ko-Shin Chen, Yu-Min Chung, Michele Coti Zelati, Hao-Wei Huang, Chun Yin Hui, Jiwon Kim, Tri Lai, Chi Yu Lo, Andrew Tapay, Chuntian Wang, and Ping Zhong (Glenn Schober Memorial Travel Award); Raphael Clouatre, Neal Coleman, Hao-Wei Huang, Deniz Kutluay, James McShane, Tristan Tager, and Will Tune (David A. Rothrock Associate Instructor Award); David Sprunger (Robert K. Meyer Graduate Fellowship in Mathematics); Aimin Huang (Award for Excellence in Research); Raphael Clouatre and Erik Wallace (William B. Wilcox Mathematics Award); Michele Coti Zelati (Charles H. Stammer Fellowship); Chun Yin Hui (Outstanding Thesis Award);

Faculty Awards

Darrell Haile received the Rothrock Mathematics Faculty Teaching Award. David Hoff, Shabnam Kavousian, Lawrence Moss, and Ji-Ping Sha won the IU Trustees' Teaching Award.

§ 2014 Awards §

Undergraduate Awards

These first-year students won awards and scholarships: Taylor Ball (Thelma Abell Prize); and Sarah Butchko (Trula Sidwell Hardy Scholarship).

These second-year students won awards and scholarships: Thomas Dauer, Max Sun Zhou, and Seth Lehman (Thelma Abell Prize); Johnathon Lowery (Cora B. Hennel Memorial Scholarship); and William Bowman and Griffin Pace (Marie S. Wilcox Scholarship).

These third-year students won awards and scholarships: Eva Loveland and Sarah Reifeis (Ruth E. Gilliatt Memorial Scholarship); Jonathan Hawkins, Thomas Boettcher, and Joseph Eskew (Cora B. Hennel Memorial Scholarship).

These fourth-year students won awards and scholarships: Brett Schrank and Megan Janke (Thelma Abell Prize); Daniel Carmody, Robert Biggs, Kevin Bauer, and Alicia Zhengyi Li (Marie S. Wilcox Scholarship); Jordan Venderley (Ciprian Foias Prize); Daniel Carmody (Rainard Benton Robbins Prize).

Laura Oehlman won the M118 Undergraduate Intern Award.

Graduate Awards

The following graduate students won awards and scholarships: Patrick Haggerty, Xuqiang Qin, and Ozan Yolasigmaz (Hazel King Thompson Fellowship); Enrique Areyan Viqueira, Yu Cao, Joshua Edge, Patrick Haggerty, Yunlin He, Matthew Heimerdinger, Marco Hernandez, Changdong Jia, Matthew Johnson, Wai Kit Lam, Mengda Lei, Tyler Mamallis, Michael Novack, Michelle Ort, Xuqiang Qin, Maxime Scott, Yi Shi, Nicholas Stanford, Sisi Tang, Ata Tuncer, Zhao Yang, Ozan Yolasigmaz, Shizhuo Zhang, Yining Zhang (College of Arts and Sciences Top Up Award); Yining Zhang (Robert E. Weber Memorial Award); Wai Kit Lam and Maxime Scott (James P. Williams Memorial Award); Fangye Shi and Junyan Xu (William B. Wilcox Mathematics Award); Michele Coti Zelati and Chuntian Wang (College of Arts and Sciences Travel Award); Ko-Shin Chen, Youngjoon Hong, Henry Horton, Aimin Huang, Zachery Lindsey, Vincent Martinez, Kyle Riggs, Ryan Vitale, Chuntian Wang, Calvin Woo (Glenn Schober Memorial Travel Award); Chuntian Wang (Joseph & Frances Morgan Swain Fellowship); William Tune (Robert K. Meyer Graduate Fellowship in Mathematics); Annie Carter (Muriel Adams Stahl Graduate Fellowship); Blake Barker (College of Arts and Sciences Dissertation Year Award); Harold Chao and Tri Lai (Outstanding Thesis Award); Arthur Bousquet, Ko-Shin Chen, Michele Coti Zelati, James Highbaugh, Ashley Lightfoot, Kiah Wah Ong, Kyle Riggs, Philip Silberman (David A. Rothrock Associate Instructor Award).

Faculty Awards

Hari Bercovici received the Rothrock Mathematics Faculty Teaching Award. Michael Damron, Jee Koh, and Bruce Solomon won the IU Trustees' Teaching Award. Linda McKinley won the Departmental Lecturer Award.

Giving

The Department of Mathematics is grateful for all of the support it receives from its generous donors. The Department has several funds to which you can give.

- Mathematics Enrichment Fund (038AS25013): Gifts to this fund will be used for the general support of the Mathematics Department, in the College of Arts and Sciences. Web access is provided through the Give link at http://www.math.indiana.edu/ Donations to this fund may also be made using the attached Indiana University Foundation Donation Form.
- Mathematics Alumni Lecture Fund (037AS25205): Gifts to this fund are used to cover the direct costs of presenting guest lectures each year on the Bloomington campus. This fund was recently established with the generosity of faculty support. Donations to this fund can be made online through
  `https://apps2.iuf.indiana.edu/og-prd/SelectAccounts.do?method=enter`
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