SMS Research News

Student research profile

Thrill of discovery motivates Zemke's research projects

Undergraduate student Andrew Zemke has caught the research bug. Since arriving at RIT in fall 2008, Drew has worked independently on multiple research projects in discrete math, inverse problems, and theoretical computer science under the guidance of Darren Narayan and Akhtar Khan at RIT and F. Blanchet-Sadri at UNC Greensboro, including participation in two Research Experiences for Undergraduates (REU) programs. "The coolest part of research is when you are the first to discover this new piece of knowledge," says Drew. His efforts have resulted in two peer-reviewed publications, one conference proceedings article, multiple conference presentations, and RIT's John D. Paliouras Award.

Drew became involved in research during his first year at RIT, although it was not originally his intention to do so. In his first quarter, he signed up for discrete mathematics with Narayan, who recognized Drew's raw talent and approached him with an independent research project. Drew envisioned research to be an abstract, theoretical process and was surprised to find many projects were computing-based. "I am glad that many of the projects appealed to my programming skill set," he says. "At the same time, I wish I had had more chances with pure math research, since that is what I plan on doing in graduate school."

Drew also has encountered his share of challenges in research. During his REU at UNC Greensboro, he and his research partner were tasked with a difficult, almost overwhelming problem. They realized their best course to make progress was to define their own problem, one related to but distinct from the original question. They were able to solve the redefined problem by developing new programming tools.

Drew also has grown personally through his research experiences. He has had the opportunity to travel to different parts of the world, including Spain, where he attended the Language, Automata Theory, and Applications 2011 conference. Although Drew is originally from Red Hook, NY, his travels have helped him to discover a new part of the country. "I really enjoyed the location of the Greensboro REU," Drew says, adding that he eventually would like to live in the Southeast. His REU experiences also introduced him to several new friends. "I still see some of them from time to time at events like the Joint Mathematics Meetings."

Faculty research profile

Strong collaborations key to Campanelli's success

In 2005, after over four decades of dedicated work, scientists figured out how to evolve moving black holes in time in numerical computer simulations. It opened up the ability to make predictions about the gravitational radiation that is emitted as binary black holes merge and that ripples through space, a phenomenon scientists hope to observe directly for the first time in the next few years. One of the first groups to publish breakthrough results in this area was Manuela Campanelli and her colleagues Carlos Lousto and Yosef Zlochower, then at the University of Texas at Brownsville. Moving to RIT soon after, Campanelli, now a Professor within the SMS, saw the opportunity for bigger and better things to come.

"The black hole breakthrough was an important step for the field, and it really opened up a huge number of avenues for further research: what happens to black holes after they merge, what happens to matter around black holes, what happens when they collide with other objects," she says. To attack so many topics, however, she knew a larger group would be needed, which led to the creation of the Center for Computational Relativity and Gravitation, or CCRG, which includes seven faculty

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School of Mathematical Sciences

SMS faculty and students participate in 2nd New York Conference on Applied Mathematics

Mathematical modeling and computation in areas such as biomathematics, mathematics of imaging, fluid mechanics, and dynamical systems were explored at the 2nd New York Conference on Applied Mathematics (NYCAM), co-organized by RIT's Center for Applied and Computational Mathematics (CACM), on Saturday,

April 30, 2011. Roughly 110 researchers from New York, the northeast, and Ontario met to discuss their work in applied and computational mathematics. The one-day conference was held at the University of Buffalo and featured talks and posters from university professors, students, and researchers working in industry. The conference strengthened connections between applied mathematicians and scientists working in the region. The CACM obtained an NSF grant to fund the NYCAM conference for three years. The 1st NYCAM was held at RIT in 2009. Further information can be obtained at the conference websites.

1st NYCAM: http://www.rit.edu/cos/math/acm/NYCAM/
2nd NYCAM: http://gibbs.math.buffalo.edu/nycam/index.html

Contributed by Tony Harkin

Recent Research Funding and Awards

Ephraim Agyingi: RIT College of Science Faculty Evaluation and Development Grant. Mathematical modeling of biological phenomena, June 2011.

Elizabeth Cherry: National Science Foundation Research Experiences for Undergraduates (supplement to grant CMMI-0800793), May 2011. Summer funding supported software engineering undergraduate student *Andrew Filipski*.

Raluca Felea: Simons Foundation Collaboration Grant for Mathematicians, 2011–2016.

Geoff W. Hotchkiss: RIT College of Science Summer Undergraduate Research Fellowship. June–August 2011. Project: Rigorous study of an inverse problem related to the manufacture of car windshields. Faculty mentor: **Akhtar Khan.**

Akhtar Khan: Simons Foundation Collaboration Grant for Mathematicians, 2011–2015.

Meagan Kuhfahl: RIT Center for Student Innovation Summer Undergraduate Research Fellowship. June–August 2011. Project: Determining malignancy of lung nodules: A quantitative approach for reducing the need for risky procedures. Faculty mentor: **Nathan Cahill**.

Benjamin Liu: RIT College of Science Summer Undergraduate Research Fellowship. June–August 2011. Project: Implications of non-uniqueness of curve fitting to sparse experimental data on dynamics of cardiac electrophysiology models. Faculty mentor: **Elizabeth Cherry**.

Lauren Kelley: Summer Undergraduate Research Fellowship (Honors Program). June–August 2011. Project: Bifurcation of the roots of the binding polynomials. Faculty mentors: **David Ross** and George Thurston.

Kara Maki: 7th International Congress on Industrial and Applied Mathematics Early Career Travel Award.

Darren Narayan, PI: National Science Foundation Research Experiences for Undergraduates in Extremal Graph Theory and Dynamical Systems Site, 2011–2014. Co-PI: **Tamas Wiandt.**

Darren Narayan: National Science Foundation STEM Real World Applications of Mathematics (Supplement), 2011–2013.

Tamas Wiandt: RIT College of Science Faculty Evaluation and Development Grant. Investigation of pulsations in the Lang-Kobayashi system with the homotopy analysis method, June 2011.

Mathematical physics inspires Bell

Mike Bell has returned to RIT three times in his young career, each time with a renewed interested in mathematics. Mike first arrived from his hometown of Barrington, RI to study computer science as an undergraduate. Although he always excelled in mathematics, the thought of being a math major did not cross his mind until after he had taken a few undergraduate courses at RIT. Mike took a yearlong break during his undergraduate studies to travel to Sweden and become fluent in the native language. Once back at RIT, Mike continued through the Bachelor of Science program where his passion for mathematics and fascination of science continued to blossom. He began to realize that science was not just a series of facts, but an active process with many open questions.
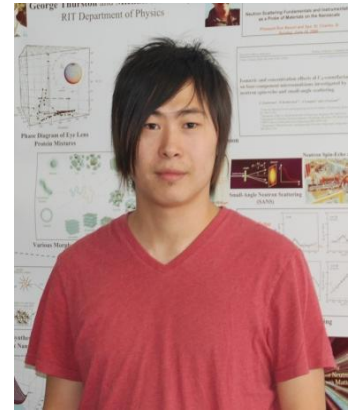
In 2008, Mike graduated and returned home only to find himself with his head buried in books by Carl Sagan and Richard Feynman. "Feynman, in particular, had a way of describing nature and science that completely changed how I looked at the world," explains Mike. He began to view the world through a scientific lens, seeing the depth and beauty in nature. "Much of this newfound sense of wonder stemmed from realizing our ability to use abstract mathematics to successfully describe physical phenomena," he says. Mike decided to further his study of mathematics and enrolled in the Master's degree program at RIT.

The topic of his thesis is modeling the phase transitions and light scattering properties of eye lens protein mixtures, namely alpha and gamma crystallin. Mike is working on deriving mathematical expressions for light scattering intensities to compare with the experimental data collected by one of his thesis advisors, George Thurston. He has been pleasantly surprised by the range of topics, including partial differential equations, linear algebra, scientific computing, complex analysis, and statistical physics, he has encountered solving this real-world problem. Through his research experience Mike has been exposed to both the experimental and theoretical sides of physics and applied mathematics. "The work I've done with [advisors Thurston and David Ross] has given me a broader perspective of how mathematics is used to do science," Mike says. "It's also been rewarding to work on a 'real' problem where your contributions, however small, could potentially advance our scientific knowledge" This work is Mike's first significant research experience, and he would encourage other students who are interested in doing research to start early.

Currently Mike is finishing his thesis and teaching college algebra at RIT. This fall he plans to apply to applied mathematics and physics Ph.D. programs. "It would be an incredible privilege to be able to devote my life to science, both learning and (perhaps) discovering how the universe works."

Drew's curiosity about mathematics began in high school and was encouraged by his enthusiastic 12th grade math teacher, Nick Ascienzo, at Red Hook High School. Drew's sights are set on becoming a mathematics professor himself, and this fall he will be applying to graduate programs. Drew encourages students interested in doing research to approach a professor to find opportunities for projects.

Around campus, Drew can be found playing the tuba in the RIT Pep and Concert Bands and faithfully attending PiRIT meetings.

Publications

Peer-reviewed research articles by **SMS faculty and postdoc** and *RIT student authors*.

Agarwal A, Lopez M, Narayan DA. Representation numbers and Prague dimensions for complete graphs minus a disjoint union of paths. *Journal of Combinatorial Mathematics and Combinatorial Computing* **78**, 97-110 (2011).

Agyingi EO, Ross DS, *Bathena K*. A model of the transmission dynamics of Leishmaniasis. *Journal of Biological Systems* **19**, 237-250 (2011).

Babiuc M, Szilágyi B, Winicour J, **Zlochower Y.** Characteristic extraction tool for gravitational waveforms. *Physical Review D* **84**, 044057 (2011).

Babiuc M, Winicour J, **Zlochower Y.** Binary black hole waveform extraction at null infinity. *Classical and Quantum Gravity* **28**, 134006 (2011).

Bartocci E, **Cherry EM,** Glimm J, Grosu R, Smolka SA, Fenton FH. Toward real-time simulation of cardiac dynamics. *CMSB 2011: Proceedings of the 9th International Conference on Computational Methods in Systems Biology,* ACM, Paris, France, p. 103-110, September 2011.

Calkin NJ, Davis J, Delcourt M, Engberg Z, **Jacob J,** James K. Discrete Bernoulli convolutions: An algorithmic approach toward bound improvement. *Proceedings of the American Mathematical Society* **139**, 1579-1584 (2011).

Cherry EM, Fenton FH. Effects of boundaries and geometry on the spatial distribution of action potential duration in cardiac tissue. *Journal of Theoretical Biology* **285**, 164-176 (2011).

Cherry EM. Mathematical models of atrial mechano-electric coupling and arrhythmias. In: Kohl P, Sachs F, Franz MR (eds.), *Cardiac Mechano-Electric Coupling and Arrhythmias,* 2nd ed. (Oxford University Press, Oxford, 2011), p. 251-257.

Chung CTY, Melatos A, Krishnan B, **Whelan JT.** Designing a cross-correlation search for continuous-wave gravitational radiation from a neutron star in the supernova remnant SNR 1987A. *Monthly Notices of the Royal Astronomical Society* **414**, 2650-2663 (2011).

Jacob J, Laskar R, Villalpando J. On the irreducible no-hole L(2,1) coloring of bipartite graphs and Cartesian products. *Journal of Combinatorial Mathematics and Combinatorial Computing* **78**, 49-64 (2011).

Jadamba B, Khan AA, Sama M. Inverse problems on parameter identification in partial differential equations. In: *Mathematical Methods, Models and Algorithms in Science and Technology* (World Scientific, 2011), p. 228-258.

Leung PK, Gammie CF, **Noble SC.** Numerical calculation of magnetobremsstrahlung emission and absorption coefficients. *Astrophysical Journal* **737**, 21 (2011).

LIGO Scientific Collaboration and Virgo Collaboration (incl. **Whelan JT**). Search for gravitational wave bursts from six magnetars. *Astrophysical Journal Letters* **734**, L35-L43 (2011).

LIGO Scientific Collaboration and Virgo Collaboration (incl. **Whelan JT**). Search for gravitational waves from binary black hole inspiral, merger, and ringdown. *Physical Review D* **83**, 122005 (2011).

LIGO Scientific Collaboration and Virgo Collaboration (incl. **Whelan JT**). Beating the spin-down limit on gravitational wave emission from the Vela pulsar. *Astrophysical Journal* **737**, 93 (2011).

Luther S, Fenton FH, Kornreich BG, Squires A, Bittihn P, Hornung D, Zabel M, Flanders J, Gladuli A, Campoy L, **Cherry EM,** Luther GE, Hasenfuss G, Krinsky VI, Pumir A, Gilmour RF Jr., Bodenschatz E. Low-energy control of electrical turbulence in the heart. *Nature* **475**, 235-241 (2011).

Melbourne A, **Cahill ND,** Tanner C, Hawkes D. Image registration using an extendable quadratic regularizer. *Proceedings of the International Symposium on Biomedical Imaging,* pp. 557-560, April 2011.

Mundim BC, Kelly BJ, **Zlochower Y, Nakano H, Campanelli M.** Hybrid black-hole binary initial data. *Classical and Quantum Gravity* **28**, 134003 (2011).

Nakano H, Campanelli M, Lousto CO, Zlochower Y. Perturbative effects of spinning black holes in the extreme mass-ratio limit. *Classical and Quantum Gravity* **28**, 134005 (2011).

Narayan DA. Intermediate minimal rankings of graphs. *Journal of Combinatorial Mathematics and Combinatorial Computing* **78**, 341-348 (2011).

Ngwa M, **Agyingi E**. A mathematical model of the compression of a spinal disc. *Mathematical Bioscience and Engineering* **8**, 1061-1083 (2011).

Ponce M, **Lousto C, Zlochower Y.** Seeking for toroidal event horizons from initially stationary black hole configurations. *Classical and Quantum Gravity* **28**, 145027 (2011).

Sergel E, Richter P, *Tran A,* Curran P, **Jacob J, Narayan DA.** Rank numbers for some trees and unicyclic graphs. *Aequationes mathematicae* **82**, 65-79 (2011).

Sundararajan L, **Kim C.** Beyond I-You-Me: An empirically supported formulation of the triadic self. *The American Sociologist* **42**, 220-231 (2011).

Winkstern T, **Cahill ND.** Rapid DFT-based variational image registration with sliding boundary conditions. *Proceedings of the International Symposium on Biomedical Imaging,* pp. 429-432, April 2011.

Zlochower Y, Campanelli M, Lousto CO. Modeling gravitational recoil from black-hole binaries using numerical relativity. *Classical and Quantum Gravity* **28**, 114015 (2011).

Conference Presentations

Conference and symposium presentations by **RIT faculty and postdocs** and *RIT students*.

Students:

Maria Barouti, Eric Spangler, and *Mingming Wang:* Segmentation of magnetic resonance images for structural modeling of the heart. RIT Graduate Research Symposium, July 2011 (poster). Faculty mentors: **Nathan Cahill** and **Elizabeth Cherry**.

Christina Battista: Mathematical models of bone remodeling at the cellular level. 2nd New York Conference on Applied Mathematics, April 2011 (poster). Faculty mentor: **David Ross**.

Zois Boukouvalas: Medical image registration using distance metric learning. RIT Graduate Research Symposium, July 2011 (poster). Faculty mentor: **Nathan Cahill**.

Anthony D. Castiglia: Mapping inspiral sensitivity of gravitational wave detectors. RIT Undergraduate Research Symposium, August 2011. Faculty mentor: **John T. Whelan**.

John A.W.B. Costanzo: Computational methods for finding the roots of a class of spectral density functions. 2nd New York Conference on Applied Mathematics, April 2011 (poster). Faculty mentor: **David Ross**.

Korinne Dobosh and *Samuel Kennedy:* The rank number of Rook's graph. Young Mathematicians Conference, Ohio State University, Ohio, August 2011 (poster). Faculty mentor: **Jobby Jacob**.

Mohamed Elshrif: Quantitative analysis of two models of human ventricular cardiac electrophysiology. RIT Graduate Research Symposium, July 2011 (poster). Faculty mentor: **Elizabeth Cherry**.

Andrew Filipski: Optimizing performance for code implementations of mathematical models of cardiac electrophysiology. RIT Undergraduate Research Symposium, August 2011 (poster). Faculty mentor: **Elizabeth Cherry**.

Geoff W. Hotchkiss: On an inverse problem of parameter identification in fourth-order partial differential equations. RIT Undergraduate Research Symposium, August 2011. Faculty mentor: **Akhtar Khan**.

Lauren Kelley: Bifurcation of the roots of the binding polynomials. RIT Undergraduate Research Symposium, August 2011. Faculty mentors: **David Ross** and George Thurston.

Meagan Kuhfahl: Determining malignancy of lung nodules: A quantitative approach for reducing the need for risky procedures. RIT Undergraduate Research Symposium, August 2011. Faculty mentor: **Nathan Cahill**.

Benjamin Liu: Non-uniqueness of curve fitting to sparse experimental data: Implications for the dynamics of cardiac electrophysiology models. RIT Undergraduate Research Symposium, August 2011. Faculty mentor: **Elizabeth Cherry**.

Brandon May: Improved image and video retrieval for different capture conditions. RIT Graduate Research Symposium, July 2011 (poster). Faculty mentor: **Nathan Cahill**.

Marcelo Ponce: Brill-wave in circumbinary disks. Astrophysical Black-hole Mergers Workshop, RIT, June 2011. Faculty mentor: **Yosef Zlochower**.

Stephen Scorse: Metrics of automated cardiac magnetic resonance imaging segmentations. RIT Undergraduate Research Symposium, August 2011 (poster). Faculty mentors: **Nathan Cahill** and **Elizabeth Cherry**.

Shaohui Sun: Globally optimized registration for serial histological sections. RIT Graduate Research Symposium, July 2011. Faculty mentor: **Nathan Cahill**.

Faculty and Postdocs:

Ephraim Agyingi, Sophia Maggelakis, and David Ross: Modeling the effect of topical oxygen therapy on wound healing. International Conference on Applied Mathematics, Modeling and Computational Science, Waterloo, Canada, July 2011.

Ephraim Agyingi, David Ross, and *Karthik Bathena*: Modeling the transmission dynamics of leishmaniasis. 2nd New York Conference on Applied Mathematics, Buffalo, NY, April 2011.

Nathan D. Cahill and *Troy Winkstern*: Rapid DFT-based variational image registration with sliding boundary conditions. International Symposium on Biomedical Imaging, Chicago, IL, April 2011.

Manuela Campanelli: Understanding black hole mergers. High Energy Astrophysics Division Meeting, Newport, RI, September 2011.

Manuela Campanelli: Merging black holes in astrophysics. Spanish Relativity Meeting, ERE2011, Universidad Complutense de Madrid, Spain, August 2011.

Manuela Campanelli: Black holes in numerical relativity. Black Holes VIII: Theory and Mathematical Aspects, Niagara Falls, NY, May 2011.

Elizabeth Cherry: Effects of the specialized conduction system on electrical wave propagation in the heart. 2nd New York Conference on Applied Mathematics, Buffalo, NY, April 2011.

Elizabeth Cherry: Alternans and nonlinear dynamics in cardiac tissue. SIAM Conference on Applications of Dynamical Systems, Snowbird, UT, May 2011.

Joshua Faber: SPH simulations of kicked disks. Astrophysical Black-hole Mergers Workshop, RIT, June 2011.

Joshua Faber: MHD and microphysics. Microphysics in Computational Relativistic Astrophysics Meeting Perimeter Institute, Waterloo, Canada, June 2011.

Raluca Felea: Microlocal analysis of FIOs with singularities. International Conference on Microlocal Methods in Mathematical Physics and Global Analysis, University of Tubingen, Germany, June 2011.

Raluca Felea and Todd Quinto: Microlocal analysis of the Slant-hole SPECT operator. Medical and Seismic Imaging workshop, University of British Columbia, Vancouver, Canada, July 2011.

Marvin H.J. Gruber: The Liu, ridge and least square estimators—A comparison. Joint Statistical Meetings, Miami, FL, August, 2011.

Gianluca Guidi and **John T. Whelan**: Status of compact binary reviews. LSC-Virgo Meeting, Orsay, France, June 2011.

Akhtar Khan: Conical regularization for some optimization problems. Applied Inverse Problems Conference, Texas A & M University, May 2011.

Akhtar Khan: Inverse problems in linear elasticity: Compressible and incompressible cases. 7th International Congress on Industrial and Applied Mathematics, Vancouver, Canada, July 2011.

Akhtar Khan: Inverse problems for quasi variational inequalities. International Congress on Industrial and Applied Mathematics, Vancouver, Canada, July 2011.

Chulmin Kim: Are there contraindications for expressive writing? American Psychological Association Annual Convention, Washington, DC, August, 2011.

Chulmin Kim: An alternative expression of the covariance structure of multivariate longitudinal data. Joint Statistical Meetings, Miami, FL, July, 2011.

Carlos Lousto: Methods and Results in 3+1 Numerical Relativity. NR/HEP Workshop, Madeira, Portugal, August 2011.

Carlos Lousto: Intermediate mass ratio black hole binaries: Numerical relativity meets perturbation theory. Numerical Relativity/Data Analysis Meeting, Cardiff, UK July 2011.

Carlos Lousto: Numerical relativity at extreme mass ratios. 14th Capra Meeting on Radiation Reaction in General Relativity, Southampton, UK, July 2011.

Carlos Lousto: Gravitational radiation recoils. Astrophysical Black-hole Mergers Workshop, RIT, June 2011.

Carlos Lousto: Gravitational recoil of astrophysical black hole binaries. Brazilian Physics Meeting, Foz do Iguaçu, Brazil, June 2011.

Carlos Lousto: Extreme-mass-ratio black-hole binaries with numerical relativity. 14th Eastern Gravity Meeting, Princeton University, NJ, June 2011.

Kara L. Maki and Y. Renardy: Yielding dynamics of a viscoelastic fluid in parallel shear flow. 7th International Congress on Industrial and Applied Mathematics, Vancouver, July 2011.

Bruno Mundim: The Einstein Toolkit and its GRMHD implementation. Astrophysical Black-hole Mergers Workshop, RIT, June 2011.

Hiroyuki Nakano: Implementation aspects of the PN BBH spacetime approach. Astrophysical Black-hole Mergers Workshop, RIT, June 2011.

Darren Narayan: Elementary applications of mathematics from RIT's Summer Mathematics Institute. Association of Mathematics Teachers of the Rochester Area, St. John Fisher College, Rochester, NY, April 2011.

John T. Whelan: Update on cross-correlation search for LMXBs. LSC-Virgo CW face-to-face meeting, Orsay, France, June 2011.

John T. Whelan: Status of compact binary reviews. LSC-Virgo CW face-to-face meeting, Orsay, France, June 2011.

John T. Whelan: A modelled cross-correlation search for Scorpius X-1. 9th Edoardo Amaldi Conference on Gravitational Waves, Cardiff, UK, July 2011.

Tamas Wiandt: Decomposition possibilities for closed relations. American Mathematical Society Eastern Sectional Meeting, Ithaca, NY, September 2011.

Yosef Zlochower: GRHD simulations of circumbinary disks. Astrophysical Black-hole Mergers Workshop, RIT, June 2011.

Yosef Zlochower: Modeling 1/10 to 1/100 black hole binaries using numerical relativity. 14th Eastern Gravity Meeting, Princeton University, NJ, June 2011.

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members (five in the SMS), along with several postdoctoral fellows, graduate students, and undergraduate researchers.

"To stay at the cutting edge of science, you really need a great team and a collaborative environment," she says, "and we've assembled a great team here combining many different skills and topics of expertise." CCRG maintains collaborations with Johns Hopkins, Georgia Tech, LSU, Caltech, and a number of other institutions. "Establishing relationships with funding agencies and the program officers at the NSF and NASA is also critical, since they provide the resources to keep a research group going," she adds. Her advice to those starting out with the grant-writing process is to consider building up a team to add breadth to project. "Science works best when we get together to share ideas and solve problems, and assembling the right team of experts in one's research field can really make the difference in getting the support to see a project through to completion."

Campanelli, looking forward, sees more excitement in store. "In a few years, we should detect gravitational waves for the first time," she says, "and we're making great strides in understanding how those detections could be combined with those from other telescopes to test out general relativity, probe our understanding of black holes, and explore the most powerful and violent processes in the universe. Computers are getting larger, the community more integrated, and RIT is poised to play a central role in all of this." Together with her colleagues, Campanelli is now working on computing light signatures and the formation of jets from merging supermassive black-holes, work which she hopes will herald the beginnings of the field of gravitational wave astrophysics.