Notre Dame Science
Department of Physics

Physics Tracks

November 2012

Two faculty named 2012 American Physical Society fellows

Two department faculty members have been named 2012 APS fellows: Prof. Bruce Bunker and Prof. Zoltan Toroczkai.

Bunker has been a member of the Notre Dame faculty since 1983, and served as department chair from 1998-2006. His research interests lie in the use of x-rays and electrons for probing the structure of solids, liquids, surfaces, and interfaces. Specifically, his group is involved with using x-ray absorption spectroscopy (XAS) and x-ray scattering to study the structure of random semiconductor alloys, solid-solid and solid-liquid interfaces, two-dimensional phase transitions at surfaces and interfaces, and structure of liquids, and systems of environmental interest. He currently serves as Chair of the Executive Committee of the International X-ray Absorption Society. He was recognized by the APS "For contributions to the development of X-ray absorption spectroscopy and applications to complex nanoscale materials."

Toroczkai joined the faculty of Notre Dame in 2006. He served as Director for the Interdisciplinary Center for Network Science & Applications (iCeNSA) from 2009-2012. He is also a Concurrent Professor of Computer Science and Engineering. Toroczkai's research interests are in agent-based systems, complex networks, biophysics, computing, and fluid dynamics. The APS named Toroczkai a 2012 fellow "For his contributions to the understanding of the statistical physics of complex systems, and in particular for his discoveries pertaining to the structure and dynamics of complex networks."

Any active APS member is eligible for nomination and election to Fellowship. The criterion is exceptional contributions to the physics enterprise; e.g., outstanding physics research, important applications of physics, leadership in or service to physics, or significant contributions to physics education. Fellowship is a distinct honor signifying recognition by one's professional peers.

Find us on Facebook

Inside this issue:

Contact information

Phone: 574-631-6386
Fax: 574-631-5952
E-mail: physics@nd.edu

225 Nieuwland Science Hall
Notre Dame, IN 46556

Web site: physics.nd.edu

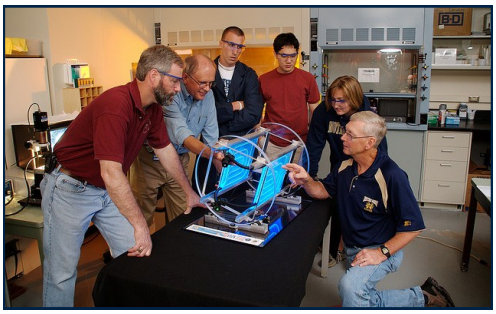
Alumni—let us know about your recent achievements and appointments. We look forward to hearing from you!

Mitchell Wayne, Department Chair
Kathie Newman, Director of Graduate Studies
Anthony Hyder, Director of Undergraduate Studies

QuarkNet program renewed by $6.1 million NSF award

Notre Dame has received a five-year, $6.1 million award from the NSF to support the continuation of the nationwide QuarkNet program, which uses particle physics experiments to inspire students, and provide valuable research, training, and mentorship opportunities for high school teachers.

Through the QuarkNet program, physicists at Notre Dame, Fermilab, and 50 other research institutions will continue to mentor teachers in research experiences, enabling them to teach the basic concepts of introductory physics in a context that high school students find exciting. Faculty, students, and teachers work together as a community of researchers, which not only develops scientific literacy in students, but also attracts young students to careers in science and technology.



Mitchell Wayne, principal investigator, said, "The Notre Dame QuarkNet Center is a great example of the mentoring and training provided by particle physicists at universities and national laboratories across the country. It has become a focal point for educational outreach into our community. Hundreds of local high school students and many of their teachers have done research in particle physics at the center."

Faculty news & notes

J. Christopher Howk, Nicolas Lehner and Grant Mathews of the Center for Astrophysics at the University of Notre Dame published a paper in September in the journal *Nature* titled "Observation of interstellar lithium in the low-metallicity Small Magellanic Cloud." The astrophysicists have explored a discrepancy between the amount of lithium predicted by the standard models of elemental production during the Big Bang and the amount of lithium observed in the gas of the Small Magellanic Cloud, a galaxy near to our own.

Boldizsár Jankó has accepted an invitation to serve on the advisory board of *Physica C: Superconductivity and its Applications*, a journal that reports on novel developments in the field of superconductivity. The peer-reviewed papers published in the journal cover topics such as the discovery of new superconducting materials, the physics of vortex matter, and the enhancement of critical properties of superconductors.

Randal Ruchti accepted a reappointment from the National Science Foundation as a program officer with their experimental high energy physics program. He is responsible for the university-based high energy physics program across the breadth of experiments in the U.S. and abroad. Prof. Ruchti will also represent NSF at major physics meetings to further the research agenda of the scientific community and the government. Additionally, he will work collaboratively within the NSF offices and directorates to further scientific and technical innovation and to advance the broader impacts of research.

Physicists Carol Tanner and Steven Ruggiero are collaborating with Notre Dame biologists to use molecular genetic tools and a new technique called laser transmission spectroscopy (LTS) to rapidly detect species-specific DNA. This technology, which fits in a small suitcase and can run off a car's battery, will be tested as a method to generate early detection in the field at sites where invasive species are suspected. The collaboration received a $599,931 Environmental Protection Agency grant under the Great Lakes Restoration Initiative to develop technologies for the early detection of invasive species using environmental DNA. Scott Egan, a research assistant professor with the Advanced Diagnostics and Therapeutics initiative, is lead researcher for the project, which also includes researchers from ND's Department of Biological Sciences, and the Environmental Change Initiative.

Zoltán Toroczkai and postdoctoral researcher Maria Ercsey-Ravasz can not only explain why some Sudoku puzzles are harder than others, they have also developed a mathematical algorithm that solves Sudoku puzzles very quickly, without any guessing or backtracking.

4	1		2	7		8		5
	8	5	1	4	6		9	7
	7		5	8			4	
9	2	7	4	5	1	3	8	6
5	3	8	6	9	7	4	1	2
1	6	4	3	2	8	7	5	9
8	5	2	7		4	9		
	9		8		2	5	7	4
7	4		9	6	5		2	8

Toroczkai and Ercsey-Ravasz, of Romania's Babeş-Bolyai University, began studying Sudoku as part of their research into the theory of optimization and computational complexity. They note that most Sudoku enthusiasts use what is known as a "brute force" system to solve problems, combined with a good deal of guessing. While the method is successful, it is also time consuming.

Toroczkai and Ercsey-Ravasz have proposed a universal analog algorithm that is completely deterministic (no guessing or exhaustive searching) and always arrives at the correct solution to a problem, and does so much more quickly. They believe their analog algorithm potentially can be applied to a wide variety of problems in industry, computer science and computational biology.

Toroczkai and Ercsey-Ravasz's methodology was first published in the journal Nature Physics, and its application to Sudoku, appears in the Oct. 11 edition of the journal Nature Scientific Reports.

A new project led by University of Notre Dame researchers will explore solutions to the problems of preserving data, analysis software and computational work flows, and how these relate to results obtained from the analysis of large data sets.

Titled "Data and Software Preservation for Open Science (DASPOS)," the National Science Foundation-funded $1.8 million program is focused on high energy physics data from the Large Hadron Collider (LHC) and the Fermilab Tevatron.

The research group, which is led by Mike Hildreth, professor of physics; Jarek Nabrzyski, director of the Center for Research Computing with a concurrent appointment as associate professor of computer science and engineering; and Douglas Thain, associate professor of computer science and engineering, will also survey and incorporate the preservation needs of other research communities, such as astrophysics and bioinformatics, where large data sets and the derived results are becoming the core of emerging science in these disciplines.

CERN computing center

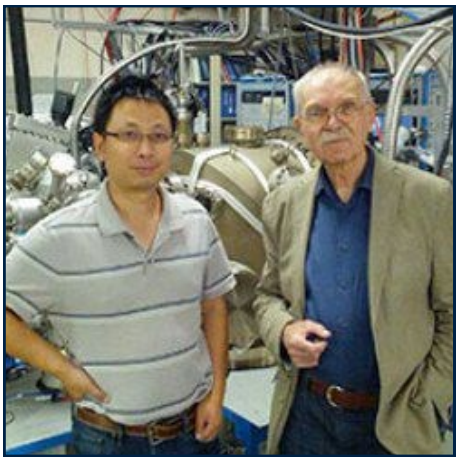
ND physicists collaborate to create a novel nanostructure that has promise for quantum computation

A team of Notre Dame and Purdue physicists. Leonid Rokhinson, Xinyu Liu and Jacek Furdyna, collaborated on experiments that allowed them to detect a long-sought-after particle referred to as the Majorana fermion. The existence of this particle has been predicted by Ettore Majorana[1] in the 1930s, but until now has eluded observation. The interest in the Majorana particle is two-fold. First, from the fundamental viewpoint, this particle has new and unique properties, ranging from its zero mass to being its own antiparticle, and to the type of statistics which it obeys. And second, because of its statistical properties (referred to as "non-Abelian"), the Majorana fermion holds promise for fault-tolerant quantum computation. It is often said that the search for this particle is for condensed-matter physicists what the Higgs boson search is for high-energy particle physicists[2,3].

The challenge in detecting the Majorana particle was to find a suitable structure in which it could reside. The team jointly designed a one-dimensional hybrid system (a "nanowire") comprised of a semiconductor (in this case indium antimonide) and a superconductor (niobium). The unique properties of this hybrid architecture then enabled the observation of the so-called fractional Josephson effect, which provided a direct signature of the sought-after Majorana particles[4].

"The key was to find a structure of sufficient quality to display this signature," Furdyna said. "This was made possible by the process of molecular beam epitaxy, which allows us to prepare complex materials systems with unprecedented purity and crystalline quality. The quality of the hybrid structures so fabricated not only enabled our team to detect the Majorana particles, but assured the reliability of the quantitative interpretation of the experiments."

The important critical step which the discovery of Majorana fermions offer toward quantum computation arises from the fact that they can be used to encode information in an extremely robust manner, in a way that is protected from so-called decoherence due to local noise by the topology of the structure in which they reside. "The information stored in the Majorana particles," Liu said, "is thus topologically protected from local environment and perturbations. That is, electrons in the circuitry cannot modify the Majorana state by scattering. In technically terms, one can say that Majorana fermions in condensed matter represent robust topological qubits." Liu added that having a crystalline structure such as that constructed by the ND/Purdue team, which can be used to "house" Majorana particles and to control them by electric and magnetic fields, already represents an important practical step toward realizing the distant—but now more realistic—goal of achieving hardware for quantum computation.



The article describing this discovery, including the details of the fractional Josephson effect and its interpretation, appears in of Nature Physics[4], accompanied by a commentary in News and Views in that journal[3]. The work was partially supported by grants from the Army Research Office and the National Science Foundation.

[1] Majorana "Teoria simmetrica dell'elettrone e del positrone" (in Italian). *Nuovo Cimento* vol 14, p. 171 (1937)

[2] http://www.purdue.edu/newsroom/releases/2012/Q3/signature-of-long-sought-particle-that-could-revolutionize-quantum-computing-seen-by-purdue-physicist.html

[3] "Majorana fermions: Doubling down on Majorana", J.R. Williams and D. Goldhaber-Gordon, *Nature Physics* Vol. 8, p. 778 (2012).

[4] "The fractional a.c. Josephson effect in a semiconductor-superconductor nanowire as a signature of Majorana particles", L. P. Rokhinson, X. Liu and J. K. Furdyna, *Nature Physics* Vol. 8, p. 795 (2012).

Barger joins Notre Dame on prestigious NSF postdoctoral fellowship

Dr. Kathleen Barger has joined Notre Dame's Department of Physics on a prestigious National Science Foundation (NSF) Astronomy and Astrophysics Postdoctoral Fellowship. A recent Ph.D. graduate of the University of Wisconsin's Department of Astronomy, Dr. Barger will explore the role gas in and around galaxies plays in galaxy evolution in collaboration with Professors Nicolas Lehner and J. Christopher Howk.

Dr. Barger's Ph.D. thesis focused on observational studies of gas in the environment of the Milky Way and its nearest neighbors in an effort to assess how such gas affects the ongoing evolution of galaxies. She made use of the Wisconsin H-alpha Mapper (WHAM), an NSF-funded observatory currently located in northern Chile, to map the otherwise-invisible gas in the Milky Way's halo and in the outskirts of the nearby Large and Small Magellanic Clouds. At Notre Dame, she will continue her work with WHAM while collaborating with Notre Dame astrophysicists Lehner and Howk to combine WHAM data with Hubble Space Telescope observations to understand the gaseous environments of the Magellanic Clouds, the nearest galaxies to our own, and to use Notre Dame's Large Binocular Telescope to study more distant galaxies.

Nuclear accelerator dedication event

Using a new $4 million particle accelerator, Notre Dame researchers are probing the mysteries of the universe. The new accelerator was dedicated at a special event on November 1.

"We're focusing on the origin of the elements in the universe," Nuclear Science Laboratory Director Michael Wiescher said.

The 5MV vertical high-beam intensity accelerator was installed on campus this year. It's housed in a 40-foot-tall tower above the Nuclear Science Laboratory in Nieuwland Science Hall. Funding for the accelerator came from a $4 million National Science Foundation grant, with the university funding an additional $4 million to build the space to contain the device.

The machine is used to simulate reactions that take place in the stars. A particle accelerator uses electromagnetic fields to propel charged particles to high speeds and to contain them in well-defined beams. Wiescher notes that most of the human body is composed of hydrogen—about half of which was formed 12 to 13 billion years ago in the Big Bang and the rest in later generations of stars.

Photos: Top right, Department Chair **Mitchell Wayne** welcomes the crowd to the dedication; middle, **Rev. John I. Jenkins**, President, blesses the accelerator; bottom right, from left to right, Wayne, Vice President for Research **Bob Bernhard**, Executive Vice President **John Affleck-Graves**, Vice President of University Relations **Lou Nanni**, and **Prof. Wiescher** tour the facility.

Graduate Physics Students (GPS) group organizes

Last year saw the formation of the Graduate Physics Students (GPS) group. According to the group's mission statement, they seek to combine the intellectual rigor of science discourse with a sustainable student network. GPS will inspire collaboration and fellowship among physics faculty and students.

The founding executive board from fall 2012 through spring 2013 included Anthony Battaglia, Danielle McDermott, Ayan Paul, and Katherine Rueff. The goal is to have student representation from each of the department's research groups. Elections occur each spring.

GPS is organized into a executive board with various committees focused on specific events or aspects of the graduate student experience. The committees include the international committee, social committee, professional development committee, and outreach committee. There is also a conference committee.

Last Spring, the GPS hosted its first Spring Conference. Graduate students in different research areas gave talks to fellow students, and posters were presented in the department's conference room. This years' conference will be held on May 1, 2013.

The GPS members volunteered at a variety of outreach activities, such as judging at science fairs and helping with the Transit of Venus event last June held on campus.

The social events hosted by the GPS included a movie night, a game night, and a trivia night. In October, they hosted a pumpkin carving event.

The professional development committee has organized gatherings with special visitors to the department, such as Nobel Laureate Brian Schmitt in the Spring of 2012. This committee also arranges meetings on CV development and fellowship applications.

GRADUATE PHYSICS STUDENTS