



From the Department Chair...

After 12 years as the chair of the physics and astronomy department, Wolfgang Bauer stepped down in May to take a position as senior consultant to the executive vice president of administrative services at MSU. After being in the department chair position for the past six months, I now truly appreciate Wolfgang's outstanding service!

The face of the astronomy and astrophysics group is changing with the retirement of professor Horace Smith and the hiring of assistant professors Jay Strader and Laura Chomiuk. In addition, the Joint Institute for Nuclear Astrophysics (JINA), an NSF Physics Frontier Center, has received funding for another year. JINA provides an exciting forum for research at the interfaces between astronomy, astrophysics and nuclear physics. Our department continues to contribute to the operation of the SOAR telescope, the Abrams Planetarium and the MSU Observatory, and we are very grateful for the support that our alumni and other donors provide to keep these operations going.

There has also been a major turnover in the condensed matter physics (CMP) group in the past five years, with the hiring of five new faculty members and the retirements of professors Michael Harrison, Jack Bass, Bill Pratt and Bhanu Mahanti. We are very fortunate that they are still coming to the office regularly! The most recent hires in CMP are Matt Comstock, Xianglin Ke and Alex Levchenko (see New Faculty section on page 3). The CMP group has an open search in the area of quantum nano-dynamics, and we look forward to continuing growth in this area.

The high energy physics (HEP) group is continuing its major efforts in the ATLAS detector experiment at the Large Hadron Collider (LHC) in Switzerland and in the tentative confirmation of the Higgs particle; with mass near 125 GeV, this advance provides strong stimulus for further experiments to study physics in the "Higgs sector." At the same time, there is an expansion of efforts in particle astrophysics through the High-Altitude Water Cherenkov Observatory (or HAWC) collaboration, and in U.S.-based neutrino experiments. A strong effort in the HEP theory group is developing parton distribution functions that are used in the analysis of many of the experiments carried out at the LHC. The HEP group has an open search for an experimentalist focusing on physics at the intensity or cosmic frontiers.

MSU nuclear physics remains top-ranked in the area, and it continues its outstanding achievements at the National Superconducting Cyclotron Laboratory (NSCL) and the Facility for Rare Isotope Beams (FRIB). NSCL has been in operation for more than 20 years and remains a key national facility for studies of low- and medium-energy nuclear structure and dynamics. FRIB has completed its planning stages and is awaiting approval of funding by Congress to break ground on construction. The facility will generate a large number of new unstable isotopes, particularly neutron-rich isotopes that are essential for understanding the way in which the element abundance of the universe came to be.

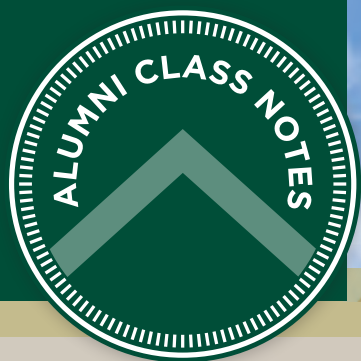
For many years, the Department of Physics and Astronomy has been at the forefront of innovations in education technologies,

including the Computer-Assisted Physics Assignments (CAPA), developed by professor Ed Kashy and his collaborators, and the Learning Online Network (LON)-CAPA system developed by professors Wolfgang Bauer and Gerd Kortemeyer. Our efforts in physics education research have been strengthened with the arrival of assistant professor Danny Caballero, whose research concentrates on transformation of physics education through problem-based instruction and community-based learning.

One of the most rewarding experiences of being a professor is to follow the success of our graduates in a diverse array of careers in academia, industry, high school teaching or careers outside of mainstream physics and astronomy, such as bioinformatics or finance. It is also great to have alumni return to the department for events such as the retirement meeting for professor Horace Smith held earlier this year. I would like to see more events like this, so if you would like to organize a retirement, reunion or other event for PA alumni it would be great to discuss it with you. Again, thanks for your support and very best wishes. ☺



*Phillip Duxbury
Chair
Department of Physics
and Astronomy*



Jack Beal, M.S., physics, '62; Ph.D., physics, '64, will retire at the end of the current academic year as past dean of the School of Engineering, professor of physics and professor of computer engineering at Fairfield University, Fairfield, Conn.

Roger Kirby, physics, '64, retired in fall 2011 after 40 years as professor of physics (including 12 years as department chair) in the Department of Physics and Astronomy at the University of Nebraska in Lincoln.

Carl Brandon, physics, '66, is now in his 37th year of teaching physics at Vermont Technical College, Randolph Center, Vt. He just completed the college's first CubeSat, a 10cm cube satellite, and delivered it to the Air Force for a Nov. 4th launch from Mid-Atlantic Regional Spaceport, Wallops Island, Va. It is the first satellite built by any college or university in New England.

Craig Barrows, physics, '67, retired from the Berkeley Hall School in Los Angeles, Calif., in 2011 and moved with his wife to Manhattan, Kan. Since retirement, he has mentored a local high school physics teacher and currently volunteers at the Flint Hills Discovery Center.

Richard Hill, physics, '68; M.B.A., marketing, '75, has published a book, *Finding Family: My Search for Roots and the Secrets in My DNA*, that shows how new genetic genealogy DNA tests can help adoptees discover their biological families. The book was named a finalist in the 2013 Next Generation Indie Book Awards, and the eBook version won a gold medal in the 2013 Global Ebook Awards.

Ronald Carter, Ph.D., physics, '71 retired in May as professor of electrical engineering at the University of Texas at Arlington, Va., and was named professor emeritus in September.

Terry McDaniel, M.A.T., physics, '71; Ph.D., physics, '73, retired from the data storage industry in 2009. He is now doing part-time research at the University of Arizona's College of Optical Sciences in Tucson and taking on occasional consulting projects.

Daniel Inman, M.A.T., physics, '75; Ph.D., mechanical engineering, '80, is chair of the Aerospace Department at the University of Michigan, Ann Arbor.

Zhi-Xiong Cai, M.S., physics, '89; Ph.D., physics, '90, is executive director, head of the credit portfolio solutions group and

senior client credit management banker for China financial solutions for J.P. Morgan in Hong Kong.

Dan Magestro, Ph.D., physics, '00, is director of the Analytics Center of Excellence at Cardinal Health in Columbus, Ohio. He is also an adjunct professor of finance at The Ohio State University, where he teaches a graduate data analysis course to business students.

Brent Barker, M.S., physics, '09; Ph.D., physics, '13, is a visiting assistant professor of physics at Roosevelt University in Chicago, Ill.

Evan De Back, M.S., physics, '10, works in game design at EA Tiburon, an Electronic Arts video game development studio in Maitland, Fla., just north of Orlando.

Jeffrey Cain, physics, '12, materials science, '12, is currently a doctoral student at Northwestern University, Evanston, Ill., in materials science and engineering. This spring, he received a National Science Foundation Graduate Research Fellowship and a National Defense Science and Engineering Graduate Fellowship.

Thanks to everyone who submitted news. Due to space limitations, we could not include all of the information that we received; however, a more comprehensive update is online at ns.msu.edu/alumni.

In Memoriam

Henry Blosser, an MSU University Distinguished Professor of physics, died March 20, 2013. Blosser was one of the pioneers in the field of accelerator physics. He came to MSU in 1958 to serve as the founding director of MSU's National Superconducting Cyclotron Laboratory and served in that role until his retirement in 1989. Under Blosser's direction, the cyclotron lab became a leading facility for nuclear physics research.

Morton M. Gordon, MSU professor emeritus, died May 29, 2012. Gordon was a professor in the department from 1959 to 1993, and then he worked for the National Superconducting Cyclotron Laboratory from 1994 to 1999. Gordon was instrumental in the design of a new breed of cyclotrons. He was known as a patient mentor and his students went on to build accelerators all over the world.

Paul Michael Parker, MSU professor emeritus, died March 4, 2013. Parker began his career in the department in 1958 and retired in 1993. He designed the original physics curriculum during his 13-year assignment with the Lyman Briggs College. This created an opportunity for Lyman Briggs students to be introduced to topics not usually treated in freshman chemistry or physics.



New Faculty

The Department of Physics and Astronomy has hired five new faculty members since its last newsletter.

2013 hires:

Marcos D. “Danny” Caballero, assistant professor, is a physics education researcher who studies how tools affect student learning in physics, and the conditions and environments that support or inhibit this learning. Caballero received his Ph.D. in physics from the Georgia Institute of Technology, Atlanta, Ga., in 2011.

Laura Chomiuk, assistant professor and National Radio Astronomy Observatory (NRAO) Jansky Fellow, researches stellar evolution, stellar explosions and the feedback effects these explosions have on star formation. She studies novae and supernovae at a range of wavelengths, with a focus on radio observations. Chomiuk received her Ph.D. from the University of Wisconsin, Madison, in 2010.

2012 hires:

Matthew Comstock, the second Jerry Cowen Endowed Chair in Experimental Physics and assistant professor, does research focused on experimental biophysics, especially using new technologies to advance single molecule biology measurement capabilities. Comstock received his Ph.D. in physics at the University of California, Berkeley, in 2008.

Xianglin Ke, assistant professor, focuses his research on exploring emergent phenomena in strongly correlated materials and complex oxide heterostructures and trying to understand the underlying mechanisms. Ke received his Ph.D. from the University of Wisconsin, Madison, in 2006.

Jay Strader, assistant professor, studies near-field cosmology with massive globular clusters and their properties, including the presence of black holes, multiple stellar populations and stellar winds from red giants. Strader received his Ph.D. in astronomy and astrophysics from the University of California, Santa Cruz, in 2007.

Second Cowen Endowed Chair continues to advance experimental physics



Matthew J. Comstock receives the Cowen Chair medallion from former MSU Provost Kim Wilcox at his installation last fall.

Matthew J. Comstock was installed as the second Jerry Cowen Endowed Chair in Experimental Physics in the MSU Department of Physics and Astronomy last fall.

Comstock, a biophysicist, received his undergraduate degree in physics from the University of Chicago and his Ph.D. in physics from the University of California, Berkeley, where he focused on optically controlled molecular machines. During a postdoctoral fellowship at the University of Illinois, Urbana-Champaign, he constructed a novel microscope capable of observing in real time the structure and function of individual biological molecular motors at the angstrom scale.

“It is a tremendous honor to be awarded the Cowen chair, and it is an especially great aid in building our new lab,” said Comstock, an assistant professor, who joined MSU in August 2012. “The increased attention and support compels us to be adventurous in the lab and push the frontiers of experimental physics.”

The endowed chair was named for Jerry Cowen, who received his Ph.D. in physics from MSU in 1954 and joined the faculty in 1955. During his tenure, Cowen excelled in both materials science research and teaching, particularly at the undergraduate level. The Jerry Cowen Endowed Chair in Experimental Physics was created by Randolph (Randy) Cowen ('74, arts and letters/Honors College), former CIO at Goldman Sachs, and his wife, Phyllis Green, in memory of his father's life and physics career at MSU.

“My father dedicated his life to research in the field of solid state physics,” Randy Cowen said. “With this endowed chair, MSU will have one of the best research efforts in the country in the field of solid-state physics; this cutting-edge research will attract a new generation of graduate students like my father.”

“We are very excited to welcome Matt to our department and are very grateful to the Jerry Cowen endowment that enables us to attract faculty of Matt's caliber,” said Phillip Duxbury, professor and chairperson of the department. “Matt's research program focuses exceptional new techniques on biological physics problems at the forefront of molecular biology.”

Physics and astronomy professor Chih-Wei Lai was installed as the first holder of this endowed chair in 2008 and still retains this position. 🍀



An illustrated history of the universe

What did galaxies look like just after the Big Bang happened, and where is dark matter located?

Megan Donahue, professor of physics and astronomy, is using information from NASA's Hubble and Spitzer telescopes and other sources to create a more complete image.

Donahue is part of a large international team that's made never-before-seen observations of some of the universe's most massive clusters of galaxies; each cluster has thousands of galaxies. They've used those clusters as giant lenses to discover two of the most distant galaxies ever identified.

"The universe is about 13.5 billion years old," Donahue said. "One of the galaxies we've discovered, lensed by these clusters, is about 13 billion years old. It's so far away that its light has been travelling for more than 13 billion years. We're seeing the galaxy as it was only about 400 million years after the Big Bang.

"The images we're creating are beautiful," she added.

Her research for the project—dubbed CLASH, partially because all the scientists are fans of the band The Clash, and mostly as an acronym for "Cluster Lensing and Supernovae with Hubble Space Telescope"—focuses on the dark matter in the clusters, including measuring each cluster's mass in three ways:

- Gravitational lens calculations: The cluster of galaxies that sits between Earth and the distant cluster of galaxies magnifies and bends the light from the distant galaxies,



This image from the NASA/ESA Hubble Space Telescope shows the galaxy cluster MACS J1206, one of 25 clusters being studied as part of the CLASH program, a major project to build a library of scientific data on lensing clusters.

which can then be seen by NASA's Hubble Telescope. The amount and location of matter in the cluster affects the observed shapes and orientations of distant galaxies, so the team uses measurements of galaxy shapes to infer the gravitational mass of the cluster.

- Gas calculations: The Chandra X-ray Telescope can see the hot gas between galaxies; the temperature and distribution of the gas, confined by the gravity of the cluster, allows Donahue to calculate how much gravity—that is, mass—the cluster has.
- Galaxy orbit calculations: By measuring the orbital speeds of the galaxies in the clusters, Donahue can then determine the amount of dark matter binding those galaxies to the cluster.

"The data are all independent of each other and are all from different sources, so we can cross-check our answers about the dark matter and be a lot more confident in our interpretation," Donahue explained. "We're in the process of analyzing everything and putting it all together. We expect to write about 10 to 20 publications from this project over the next year.

"Everyone is working hard to learn as much as we can from these data," she continued. "We know that the Hubble Space Telescope won't last forever and it's unlikely that a project like ours would be repeated." 🌟

Retirements

Four Department of Physics and Astronomy faculty members retired in 2013:

Don David Batch, adjunct instructor and director of Abrams Planetarium, retired in January after 44 years at MSU. Batch served as director of the planetarium from 1982 until his retirement. He received his Ph.D. from Michigan State University, East Lansing, Mich., in 1991.

Tim Beers, University Distinguished Professor emeritus, retired in January after 27 years in the department. Beers' research

focused on the oldest stars in the universe. Some of the stars he identified have detectable radioactive decay lines, such as thorium, which are now being used to measure the age of the universe. Beers received his Ph.D. from Harvard University in 1983. He is now the director of Kitt Peak National Observatory in Arizona.

S. D. Mahanti, professor, retired in August after 43 years in the department. Mahanti focused his research program on a fundamental understanding of the physics of self-assembly of amphiphiles and

physical properties of confined particles inside meso- and nanoporous media. He received his Ph.D. from the University of California, Riverside, in 1968.

Horace Smith, professor, retired in May after 32 years in the department. Smith is one of the world's experts on the nature of the pulsating stars known as RR Lyraes and Cepheids. He used the SOAR telescope to study variable stars in stellar systems at distances in excess of a million light years from Earth. Smith received his Ph.D. from Yale University in 1980.

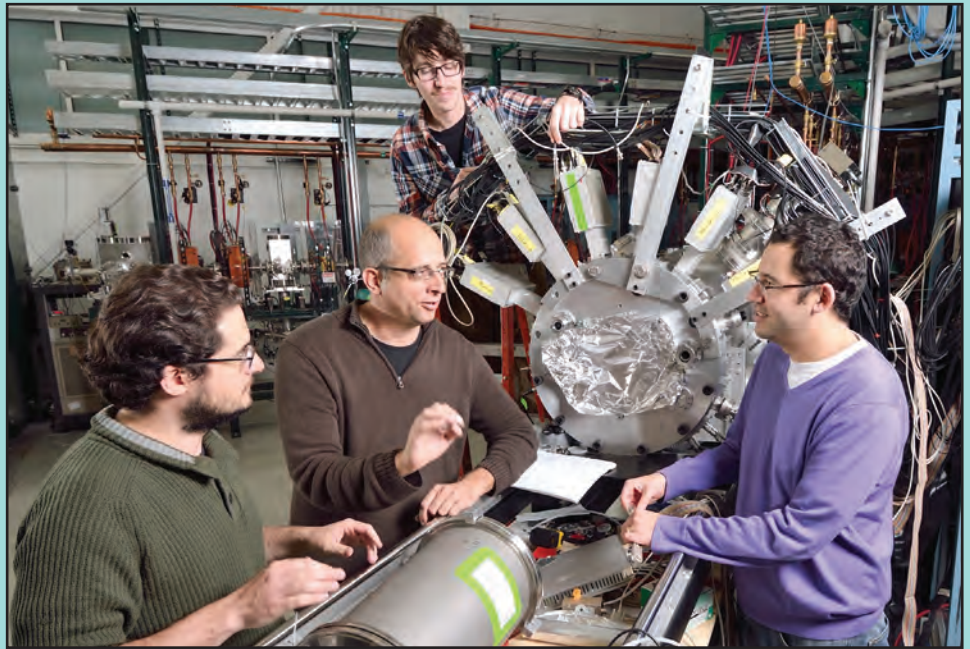
The origins of the elements

When a nuclear astrophysicist looks at the periodic table, he or she knows the origins of the elements up to number 26—iron. After that, the elements get heavier and elemental history gets murkier.

“We don’t know exactly where the heavier elements came from,” said Hendrik Schatz, professor of physics and astronomy, whose research explores nuclear processes in the cosmos. “The rare radioactive isotopes must capture another neutron faster than they can decay. This is called the r-process and it happens in milliseconds.

“It’s been theorized that the heavier elements are made as exotic isotopes in extreme environments such as supernovae or colliding neutron stars,” he continued. “The exotic isotopes then decay into stable isotopes. Figuring out how to model this process in the lab is one of the top 11 questions of the century.”

Similar exotic isotopes are powering hydrogen explosions on neutron stars and white dwarfs, or form the crusts of neutron stars. In Schatz’s lab in the National Superconducting Cyclotron Laboratory (NSCL), he creates the same short-lived nuclei that are produced in astrophysical explosions and studies their properties to look for answers to origins of the heavy elements in the universe or the nature of neutron stars.



Physics and astronomy professor Hendrik Schatz (center left) discusses details of the new NSCL ReA3 reaccelerated beam line with staff physicist Fernando Montes (right) and research associate Antonio Kontos (left front), as fourth-year graduate student Zach Meisel listens in.

“We’re carrying out a number of different types of experiments. These include: measuring neutron emission with the NERO detector developed by our group; using the new generation gamma ray detector array GRETINA to measure the excited states of exotic nuclei that are then used to calculate reaction rates for X-ray bursts; and measuring the masses of very neutron-rich nuclei needed in neutron star crust models using the S800 spectrometer and a set of specially developed micro channel plate and fast plastic detectors,” Schatz said. “The new ReA3 reaccelerated beam facility at NSCL will produce beams of rare isotopes at low energies that match the temperatures in astrophysical environments, so we’ll be using that facility as well.”

Once scientists understand the properties of rare isotopes, they can calculate the characteristic pattern of elements created in various types of astrophysical explosions and compare them to the patterns found in nature. With this information, the origin of the elements and the contributions of various astronomical events can be disentangled.

Similarly, information from rare isotopes allows scientists to calculate the X-ray brightness of neutron stars, which can be compared with satellite observations to learn about the nature of these stars and the extremely compact matter they contain.

Schatz’s research program is part of the Joint Institute for Nuclear Astrophysics (JINA), an international network of institutions and researchers that brings together nuclear physicists and astrophysicists. JINA is one of the National Science Foundation’s Physics Frontier Centers. Through the JINA network, research with larger-scale models of supernovae or star evolution can be directly linked to observational programs at the largest telescopes and to experiments at many of the world’s leading accelerator facilities. Graduate students in Schatz’s lab can conduct research at JINA collaborating institutions in the United States and abroad, enhancing the depth and breadth of their work. There are also undergraduate programs through JINA.

“JINA has been very successful—it creates collaboration across different disciplines,” Schatz said. “It’s a good example of what these types of centers can do. It offers 20 to 30 programs a year with thousands of participants. In addition to research, education and outreach are major components of JINA.”

Schatz and his colleagues are currently working on a second JINA proposal to extend and expand the collaboration for five more years. 🍀

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Photographs courtesy of: CERN, MSU Office of Communications and Brand Strategy, NASA/ESA and Harley Sealey.



Facility for Rare Isotope Beams gains ground

In August, the Department of Energy's Office of Science (DOE-SC) approved the integrated cost, scope and schedule for the construction of the Facility for Rare Isotope Beams (FRIB), which will be located on the MSU campus.

FRIB is a new, national user facility for nuclear science funded by the DOE-SC and operated by MSU. The facility will enable scientists to make discoveries about the properties of rare isotopes to better understand the physics of nuclei, nuclear astrophysics, fundamental interactions and applications for society in medicine, homeland security and industry.

The heart of FRIB is a high-power superconducting linear accelerator that supports all cutting-edge methods of producing rare isotopes. Particle accelerators, including the superconducting linear accelerator at the core of FRIB, enable the production and study of isotopes not commonly found in nature that have a host of basic and applied uses.



“When completed, FRIB will provide access to completely uncharted territory at the limits of nuclear stability, revolutionizing our understanding of the structure of nuclei as well as the origin of the elements and related astrophysical processes,” said Thomas Glasmacher, University Distinguished Professor of physics and FRIB project manager.

“The facility will support a research community of more than 1,000 scientists from around the world.

U.S. News and World Report named MSU's nuclear physics doctoral program the nation's best last year.

“The facility will also be critical to educating the next generation of scientists,” Glasmacher said. “The prospect of FRIB building on the National Superconducting Cyclotron Laboratory's reputation as a world-leading rare isotope facility helps the university continue to attract world-class students and scientists.”

The total cost for the FRIB project is \$730 million, of which \$635.5 million will be provided by DOE and \$94.5 million will be provided by the state of Michigan and MSU. The project will be completed by 2022.

For more information on the FRIB project, visit www.frib.msu.edu.

Faculty Honors

Georg Bollen, professor of physics and astronomy and director of the experimental systems division for the Facility for Rare Isotope Beams (FRIB), was named University Distinguished Professor in 2013. Bollen is one of the world's most accomplished physicists working at the interface between atomic and nuclear physics. Among his many contributions, Bollen established a low energy beam and ion trap, the first — and so far only — Penning trap mass measurement program for rare isotopes produced in flight. He has also been a key player in MSU's bid for FRIB and in research and development that laid the foundation for important parts of FRIB design.

John McGuire, assistant professor of physics and astronomy, received a 2012 NSF Faculty Early Career Development (CAREER) Award for his study of vibrational relaxation, orientational dynamics, and couplings between vibrational modes of water at aqueous interfaces.

Elizabeth H. Simmons, professor of physics and astronomy and dean of Lyman Briggs College, was named University Distinguished Professor in 2013. She has an international reputation in theoretical particle physics as an expert on the origins of electroweak symmetry breaking, the nature of the top quark, and the prospects for discovering new particles and forces. Simmons is also a nationally recognized leader in supporting underrepresented groups in the sciences. In addition, Simmons was named an American Council on Education Fellow for the 2013-14 academic year.

Michael R. Thoennessen, professor of physics and astronomy and associate director of the National Superconducting Cyclotron Laboratory at MSU, received the 2012 American Physical Society Division of Nuclear Physics Award for his dedication to attracting, nurturing and mentoring young people in nuclear science.

G. Mark Voit, professor of physics and astronomy and associate dean for undergraduate studies in the College of Natural Science, was named a 2013 Fellow of the American Association for the Advancement of Science. Voit was recognized for his efforts to further understand both cosmological and astrophysical aspects of galaxy clusters and for distinguished contributions to public outreach and university-level education in astronomy.

Stephen Zepf, professor and associate chair of the Department of Physics and Astronomy, was honored at the 2013 MSU Awards convocation in February with a Distinguished Faculty Award. Zepf is the world leader in the investigation of globular cluster systems and successfully predicted the formation of globular clusters in galaxy mergers. He discovered the first known black hole in a globular cluster.

Making molecular movies

Electron microscopes allow scientists to see the structure of microorganisms, cells, metals, crystals and other tiny structures that weren't visible with light microscopes. But while these images have allowed scientists to make great discoveries, the relationship between structure and function could only be estimated because the images were static. In the 1990s, researchers started to add a fourth dimension—time—by using a laser to capture images of gaseous molecules as they were reacting.

Now, Chong-Yu Ruan, associate professor of physics and astronomy, is working to bring these “molecular movies” down to the nanoscale level, where the properties of materials begin to change. The work has applications in nanoelectronic technologies and in clean energy industries such as photovoltaics and photocatalysis.

“Our research team is one of a handful of groups in the world actively developing ultrafast electron diffraction and imaging technologies for studying materials and molecular processes in the ultrafast time scale and with atomic scale resolution,” Ruan explained. “The goal is to understand the nature of physical, chemical and biological transformations.”

Ruan learned from the best. He worked as a postdoctoral scholar in the laboratory of Ahmed Zewail at the California Institute of Technology. Zewail received the Nobel Prize in Chemistry in 1999 for his research using femtosecond spectroscopy to show how atoms in a molecule move during a chemical reaction. One femtosecond is one-millionth of a nanosecond or 10^{-15} of a second. In a sense, the device is the world's fastest camera. It uses laser flashes of such a short duration



MSU doctoral students Kiseok Chang (top to bottom), Zhensheng Tao and Jenni Portman played key roles in the development of a phase one nanoscale imaging device, which will allow scientists to access the multi-scaled world of matter, with the ability to zoom in on atoms and molecules.

that they actually can illuminate what happens during chemical reactions.

Ruan is expanding the work to ultrafast electron crystallography, which allows him to look at nanocrystals, their bonds, and how they're affected by their surfaces and water. He's also working to develop a radio frequency-enabled, high-brightness electron microscope for studying complex materials and nanofilm solution phase chemical and biological processes.

In 2010, Ruan received a U.S. Department of Energy special instrument grant to set up a femtosecond lab at Michigan State. In 2011, he and MSU collaborators Martin Berz and Phillip Duxbury, both professors of physics and astronomy, and Martin Crimp, professor of chemical

engineering, were awarded a National Science Foundation major research instrumentation grant to begin building a device.

Both graduate and undergraduate students work on the instrument project; one graduate student whose doctoral work was based on the grant is now at Thomas Jefferson National Accelerator Facility in Virginia.

“We're working at the nanoscale level because everyone wants everything to be faster and smaller: computers, phones, scientific devices,” Ruan said. “We've built the first phase of a nanoscale imaging device to see material processes at that scale based on ultrafast electron crystallography. It's challenging to make the imaging faster and able to work at a smaller scale given the strong repulsive forces among the electrons that are packed into femtosecond pulses. You have to pack the same amount of electrons into a smaller space and time. We hope to do our first experiment in a few months.

“At the bottom of the length scale for material investigations, everything looks like a big molecule,” he continued. “Now we're beginning to have access to the multi-scaled world of matter, with the ability to zoom in on atoms and molecules.”

Ruan and his collaborators filed a patent on the device last year. He envisions it being an “add-on” to an electron microscope, allowing scientists to extend the capabilities of these devices.

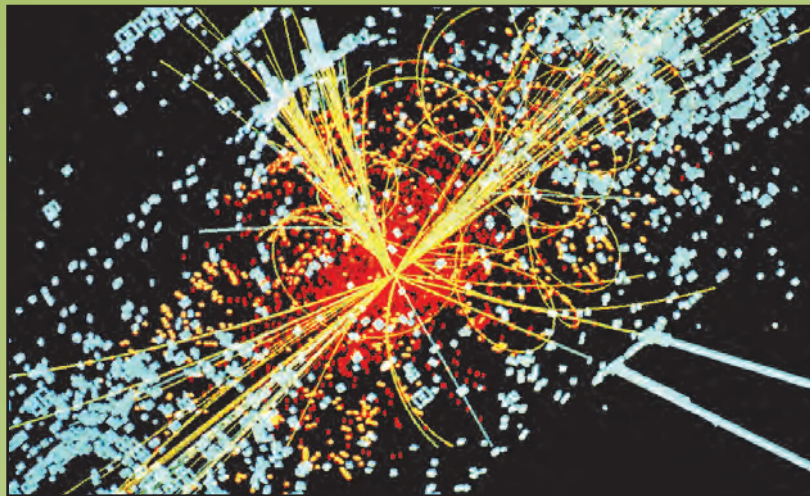
“An electron microscope costs between \$1 million and \$10 million,” Ruan said. “I expect our device to cost about \$500,000. It would allow electron microscopes to be updated with high temporal resolution for less money than buying a new one.”

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What's next after the Higgs boson?

Michigan State University Distinguished Professor of physics Chip Brock was a member of one of the international teams of physicists from the European Organization for Nuclear Research, known as CERN, who discovered the Higgs boson in July 2012.

A particle physicist, Brock—along with nearly 20 other MSU scientists and students, including PA faculty members Wade Fisher, Joey Huston, Jim Linnemann, Bernard Pope, Kirsten Tollefson and Reinhard Schwienhorst—has been a member of the ATLAS collaboration at CERN since the 1990s. Involving about 3,000 scientists from 38 countries, the ATLAS experiment studies proton collisions and the debris they leave behind to understand the basic forces that have shaped the universe. Both ATLAS and CMS, another huge CERN experiment, independently confirmed the existence of the Higgs boson.



One possible signature of a Higgs boson from a simulated collision between two protons.

The Higgs boson plays an integral role in the standard model, one of the most prominent theories describing how the universe works. The standard model says that the universe is made up of 12 matter particles and four forces. Each force also has a corresponding carrier particle, or boson, that acts upon matter according to particular laws. The matter particles have no natural mass, but gain mass by passing

through the Higgs field, which affects different particles in different ways, corresponding to the mass that they exhibit.

Now that the existence of the Higgs boson has been confirmed, what's next for particle physics?

“We need to measure precisely what the Higgs boson does and how it reacts because the standard model is really only a generic description and is very unlikely to be

the final story,” Brock explained. “It's too contrived. Establishing the more realistic theory will take decades of research because of the years of data-taking that will be required. Any extension of the standard model will entail additional particles and forces. We'll also have to find new particles that add to the standard model and make it part of a bigger description of nature.”