FALL 2015

DEPARTMENT OF

Physics & Astronomy

MSU College of **Natural Science** | *Newsletter for Alumni and Friends*

From the Department Chair...

Greetings and welcome to the 2015 issue of our newsletter. As you'll see, this has been a busy and productive year for the department.

Three new faculty members joined the department (see page 3) and we have open searches for three theory faculty members—two in quantum chromodynamics (QCD) and one in condensed matter theory. Two more positions in lattice QCD will be filled in the newly created Department of Computational Mathematics, Science and Engineering (CMSE) and the Facility for Rare Isotope Beams (FRIB).

The CMSE department is an exciting development on the MSU campus and has close ties to the physics and astronomy department through joint hires in astrophysics, nuclear theory, QCD and condensed matter theory. New joint undergraduate and graduate programs in computational physics will be developed in the next couple of years in collaboration with CMSE.

Several notable faculty awards have been received in the past year, including a Packard Fellowship to Jay Strader, whose work focuses on black holes. The last time a faculty member at MSU received this prestigious award was 1995! Read more about Jay's research and other faculty honors on page 4.

There has been a changing of the guard—and a name change—of the nuclear physics laboratory at MSU. It is now known as the Facility for Rare Isotope Beams (FRIB) Laboratory, and Konrad Gelbke has stepped down as director after an illustrious career in both research and laboratory leadership (see profile on page 7). A smooth transition has been made with Thomas Glasmacher, who is the new FRIB director.

The National Superconducting Cyclotron Laboratory will continue to operate until at least 2020, and first beam at FRIB is scheduled for 2022. The Department of Energy has approved the establishment of an expanded theoretical nuclear physics program, FRIB theory, to support the experimental programs associated with FRIB. A collaboration with China—FRIB China— is also being developed, adding further momentum to the science programs associated with FRIB.

". . . this has been a busy and productive year for the department."

Astrophysics research in the department continues to strengthen, encompassing the JINA-CEE NSF Physics Frontier Center for nuclear astrophysics, the particle astrophysics programs in the HAWC high energy gamma-ray detector in Mexico (see page 11) and the ICECUBE neutrino detector at the South Pole. The theoretical programs in astrophysics have published several high-profile studies this year, including modeling of the ways that stars are born (page 8) and computational studies of supernova explosions (page 12).

Several undergraduate and graduate student groups in the department are very active, including the Society of Physics Students (SPS); The Physics-Astronomy Department Graduate Student Organization (PGO); and a new club that started this year, the Applied Physics Club, a group of students interested in building devices or machines that are intriguing and useful. The Women and Minorities in Physical Sciences (WaMPS) group was featured in the American Physical Society's fall 2015 newsletter, the *Gazette*, and Science Theatre took their traveling show to Michigan's Upper Peninsula again during summer 2015. These groups add to the general positive and engaged atmosphere of the department, and we thank the participating students for the hard work required to make these efforts effective.

There is a strong push across the MSU campus toward a transformation in the way that introductory STEM courses are delivered and assessed. Our department has long been a leader in STEM education at MSU, and this has been given strong impetus by the new Physics Education Research Laboratory (PERL). A new problem-based introductory course has been developed, and scale-up of this course to sections with up to 100 students is planned for fall 2016. Read more about PERL on page 9.

In closing, I want to encourage you to let us know about important alumni news and to visit us when you are in town. Thanks, as always, for your support and best wishes for the coming year!

Phillip Duxbury
Chair
Department of Physics and Astronomy

ALUMNI CLASS NOTES

Thomas A. Natiello, Ph.D., physics, '59; master's, personnel administration, '63; Ph.D., general business administration, '66, has been appointed chairman of the Quality Assurance and Compliance Committee of Santa Fe Health Care, Gainesville, Fla., for which he serves as a member of the board of directors.

William J. Skocpol, B.A., physics, '68, was recently promoted to Professor Emeritus by the Boston University Department of Physics, where he taught more than 4,000 students during his 26 years of service.

John McIntyre, physics, '70; M.A., English Secondary School Teaching, '72, and his band, They're Dead, played at Mac's Bar in East Lansing, Mich., in August as the opening act for Darsombra.

Jeff Creasy, M.D., physics, '76, is professor of radiology and section head of neuroradiology at Vanderbilt University in Nashville, Tenn.

David Ball, physics, '81, is employed in product security and project management with GE Aviation Systems in Grand Rapids, Mich.

Frank Sottile, physics and mathematics, '85, is a professor of mathematics at Texas A&M University in College Station.

Robert Wood, mathematics '87; M.S. physics, '89; M.S., computer science, '93, has been in Silicon Valley for the past 15 years and currently works at Vocera, San Jose, Calif. He recently received a U.S. patent for his invention titled "System and Method of Automated 3D Scanning for Vehicle Maintenance."

Benn Tannenbaum, Ph.D., M.S., physics, '93, was elected a fellow of the American Physical Society.

Zach Constan, Ph.D., M.S., physics, '00; Ph.D., physics, '02, recently completed his ninth year as outreach coordinator for the National Superconducting Cyclotron Laboratory at Michigan State University in East Lansing, Mich. He's performed public education for more than 50,000 people through tours, talks, camps, science festivals and other events. Constan recently received the Jack Breslin Distinguished Staff Award to recognize his service to MSU.

Dan Magestro, Ph.D., physics, '00, is the new vice president, research director for the International Institute for Analytics in Portland, Ore.

Jaehyon Rhee, Ph.D., astrophysics and astronomy, '00, recently joined the Harvard-Smithsonian Center for Astrophysics' SAO Telescope Data Center, Cambridge, Mass., as a data archive scientist.

Nathan Frank, Ph.D., M.S., physics, '01; Ph.D., physics, '06, was recently promoted to associate professor at Augustana College in Rock Island, Ill.

Ana Rosas, astrophysics, '01, has a new position constructing science degree curriculums and doing data analysis of food habits at Arizona State University in Phoenix.

Carlos O. Maidana, Ph.D., M.S. physics, '03, is owner and managing director of an engineering design and scientific research technical office selected for the 2015 Small Business Innovation Research Award in advanced nuclear technologies by the U.S. Department of Energy. Maidana was also selected to lead the design of liquid metal magnetohydrodynamic components in the reactivation of the Transient Reactor Test Facility at the Idaho National Laboratory.

Aaron Adair, Ph.D., physics, astrophysics and mathematics, '08, is a visiting assistant professor of physics at Merrimack College in North Andover, Mass. He graduated from The Ohio State University in 2013 with a Ph.D. in physics. That year he published his first book, The Star of Bethlehem: A Skeptical View, and participated in a conference on the subject of the book at the University of Groningen in 2014.

Andrew Keller, Ph.D., physics, and East Asian languages and culture, '13, received his Ph.D. in physics at Stanford University in California in June 2015, and is currently a postdoctoral fellow at the Institute for Quantum Information and Matter, California Institute of Technology in Pasadena. He just published a letter in Nature titled, "Universal Fermi liquid crossover and quantum criticality in a mesoscopic system."

Nathan Wasylewski, physics, '13, is a design and development engineer at Market Technologies, Inc., Elmira, Mich. He is the only engineer at the company that bridges all three of its departments—quality and testing, CAD engineering and management, and product development.

Contact Us

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Photographs courtesy of: Harley J. Seeley, CERN (page 5, top), Sean Couch (page 12), Greg Kohuth, MSU Office of Communications and Brand Strategy (page 4), and NASA/CXC/STSci/DDS/Magellan (page 10).

Handzy receives NatSci Outstanding Alumni Award

Damian Handzy (Ph.D., physics, '95), who earned his doctorate while working at MSU's National Superconducting Cyclotron Laboratory, received the Outstanding Alumni Award at the annual awards program of the College of Natural Science Alumni Association, which was held April 24 at MSU's Kellogg Hotel and Conference Center.

For the past 18 years, Handzy has been a leader in the field of financial risk management. He is chairman and CEO of Investor Analytics (IA), which he co-founded in 1999 after working as a manager for Deloitte & Touche for four years. As a result of providing clients an advanced, intuitive and easy-to-use technology platform, IA was recognized with three industry awards in 2010, including *Risk Magazine's* Software Product of the Year, and with two awards in 2015, including *SmartCEO's* Deals of Distinction Award.

Handzy advocates incorporating advancements from related disciplines to improve risk management, especially lessons from behavioral economics, cognitive science, complexity theory and natural selection, so that IA can help clients understand the decision-making process that leads to success.

"Damian Handzy is richly deserving of the NatSci Outstanding Alumni Award," said Phillip Duxbury, professor and chair of the Department of Physics and Astronomy. "His success story outside of mainstream physics provides inspiration for young physicists interested in expanding their choices beyond conventional physics and astronomy careers."

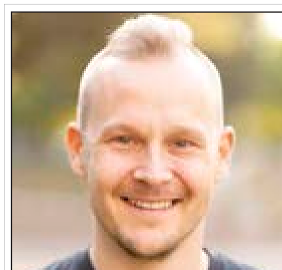
Handzy

New Faculty

Sean Couch joined the Department of Physics and Astronomy and the Department of Computational Mathematics, Science and Engineering as an assistant professor in June 2015. He specializes in computer simulations of astrophysical processes, especially aspects of core-collapse supernovae. Couch was a Hubble Fellow at the Flash Center of the University of Chicago Department of Astronomy and Astrophysics from August 2011 through September 2014, and a Senior Postdoctoral Scholar at the California Institute of Technology from October 2014 to June 2015. He received his Ph.D. in astrophysics from the University of Texas at Austin.

Heiko Hergert joined the National Superconducting Cyclotron Laboratory in 2014 and became a joint assistant professor in the Department of Physics and Astronomy in the fall of 2015. His research combines renormalization group techniques and computational many-body theory to develop efficient methods for the description of nuclei from first principles, from light isotopes of carbon to the tin isotopic chain and beyond. He is currently developing tools to calculate the properties of entire chains of open-shell nuclei, which will increase the number of accessible isotopes more than tenfold. Hergert received his Ph.D. in physics from Technischen Universität Darmstadt, Germany.

Johannes Pollanen will hold a Cowen Chair in Experimental Condensed Matter Physics as an assistant professor in the Department of Physics and Astronomy beginning in January 2016. He is currently an Institute for Quantum Information and Matter (IQIM) postdoctoral scholar at the California Institute of Technology. His primary research interests are exploring the fundamental physics and potential quantum information (QI) applications of low-dimensional electrons and hybrid quantum systems. He earned his Ph.D. in physics from Northwestern University, where he and his colleagues discovered a new exotic superfluid state of 3He.



NatSci astronomer awarded Packard Fellowship

Michigan State University astronomer **Jay Strader** has been named a fellow of the David and Lucile Packard Foundation, a prestigious award that honors the country's most innovative early-career scientists.

Strader and 17 other fellows will each receive a grant of $875,000 over five years to pursue their research.

Strader

The Packard Foundation established the national program in 1988 to provide early-career scientists with flexible funding and the freedom to take risks and explore new frontiers in their fields.

"I am humbled to have been selected and am honored to represent MSU as a Packard Fellow," said Strader, an assistant professor whose work focuses on black holes. Specifically, he discovers and studies black holes in the dense stellar environments of globular clusters using data from optical, X-ray and radio telescopes. This work sheds light on the formation of black holes in the death throes of massive stars and helps guide tests of Einstein's theory of general relativity.

Strader has been an MSU faculty member since 2012. He was a Hubble Fellow and Menzel Fellow at the Harvard-Smithsonian Center for Astrophysics from 2007 to 2012. Strader earned his Ph.D. at the University of California, Santa Cruz.

Only two other MSU faculty members have received a Packard fellowship: Kay Holekamp, University Distinguished Professor of zoology (1993), and Marcos Dantus, University Distinguished Professor of chemistry (1995).

Professor **Alexandra Gade** received the 2015 Zdzisław Szymański Prize in recognition of her leadership in the exploration of the structure of exotic nuclei at the extremes of neutron to proton ratio and, in particular, for her seminal studies of spectroscopic factors in nuclei far from the valley of nuclear stability. The award ceremony and a lecture delivered by Gade took place during the XXXIV Masuria Lakes Conference of Physics, which was held September 6–13, 2015, in Pulaski, Poland.

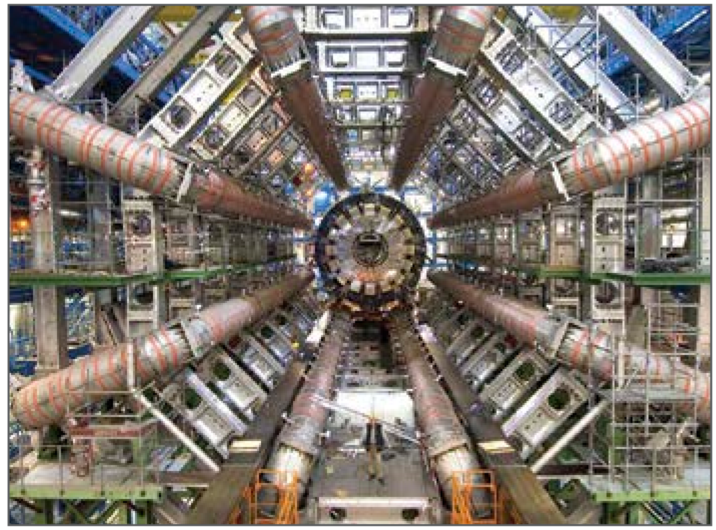
Three Department of Physics and Astronomy faculty members were named 2015 University Distinguished Professors in recognition of their achievements in the classroom, laboratory and community. **Marcos Dantus**, adjunct professor of physics and astronomy, and professor of chemistry, was honored for pioneering the use of spectrally and temporally shaped ultrafast pulses as photonic reagents to probe molecular properties, control chemical reactions and for practical applications such as biomedical imaging; **Hendrik Schatz,** who heads the Joint Institute for Nuclear Astrophysics – Center for the Evolution of Elements and is a faculty member of the National Superconducting Cyclotron Laboratory (NSCL) and the Facility for Rare Isotope Beams (FRIB), was recognized for his research with rare isotopes that address open questions in astrophysics, such as the origin of the elements or the nature of stellar explosions; and **Michael Thoennessen,** associate director for user relations at FRIB and a faculty member of the NSCL, was honored for research on nuclei beyond the end of the nuclear chart, or neutron-unbound nuclei.

Associate Professor **Brian O'Shea** received a Teacher-Scholar Award at the annual MSU Awards Convocation Feb. 10, 2015, for his devotion to and skill in teaching, and for instruction that is linked to and informed by his research and creative activities.

Large Hadron Collider receives funding support

Associate professors Wade Fisher and Reinhard Schwienhorst are the principal investigators on projects to upgrade the Large Hadron Collider, the world's largest and most powerful particle accelerator. Fisher and Schwienhorst received a $2.8 million grant from the National Science Foundation (NSF) and the U.S. Department of Energy that runs from 2014 to 2018 to support Phase 1 upgrades to the collider. Fisher is also working on planning and funding for Phase 2 upgrades. He received a $560,000 grant from the MSU Office of the Vice President for Research to fund research and development. To complete the upgrades, Fisher is seeking an NSF grant that would run from 2019 to 2024. Collaborators on the project include MSU physics and astronomy research specialists Daniel Edmunds, Philippe Laurens and Yuri Ermoline.

The Large Hadron Collider was built by the European Organization for Nuclear Research (CERN) between 1998 and 2008 in collaboration with 10,000 scientists and engineers from more than 100 countries, as well as hundreds of universities and laboratories. The MSU team works on the ATLAS detector that is searching for new discoveries in head-on collisions of protons of extraordinarily high energy. Phased upgrades of the collider will improve the physics research potential by capitalizing on advancements in high-speed electronics and detector capabilities. The MSU projects dovetail with upgrades being done by ATLAS collaborators across the U.S., Europe and Asia.



The Large Hadron Collider in Switzerland is the world's largest and highest-energy particle accelerator complex, intended to collide opposing beams of protons charged with approximately 7 TeV of energy.

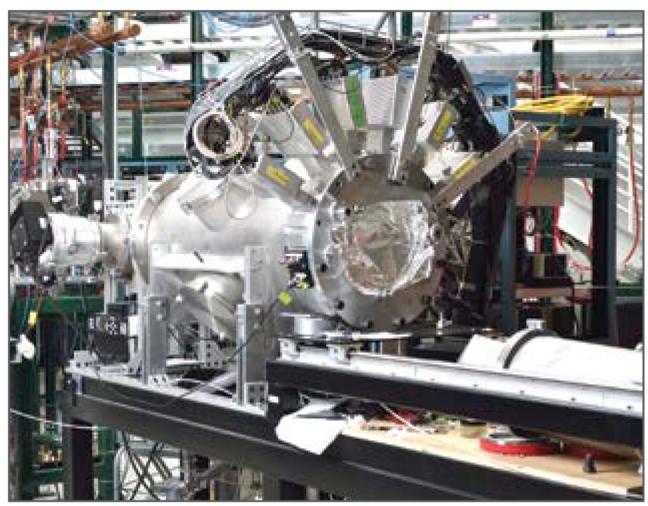
NSF continues funding for MSU's JINA Physics Frontiers Center

The National Science Foundation announced that it will continue funding the MSU-based Joint Institute for Nuclear Astrophysics – Center for the Evolution of the Elements (JINA-CEE) and that it will continue to be designated as a Physics Frontiers Center. The center, headed by University Distinguished Professor Hendrik Schatz, studies how the elements found throughout the universe first came to be and explores two closely related topics: The origin of the elements beyond those created during the Big Bang and the nature of dense nuclear matter that makes up the cores of neutron stars and their remnants.

JINA obtains and then combines data from accelerator experiments, astronomical observatories, computer simulation and theoretical calculations to understand how the elements that make up the world have been created in stars and stellar explosions. It brings together nuclear experimentalists and theorists, astronomers, theoretical astrophysicists and computational physicists from around the world.

Other partners in the JINA-CEE project include Arizona State University, the University of Notre Dame, the University of Washington and 18 other institutions from six countries.

The Physics Frontiers Centers (PFC) program supports university-based centers and institutes where the collective efforts of a larger group of individuals can enable transformational advances in the most promising research areas of physics, including atomic, molecular, nuclear, gravitational and biological physics.



MSU is leading an NSF-funded research project that is studying how the elements of the universe evolved.

Building a better semiconductor

Research led by Michigan State University could someday lead to the development of new and improved semiconductors. The scientists have developed a method of using ultrafast light pulses to control the current flow in these materials.

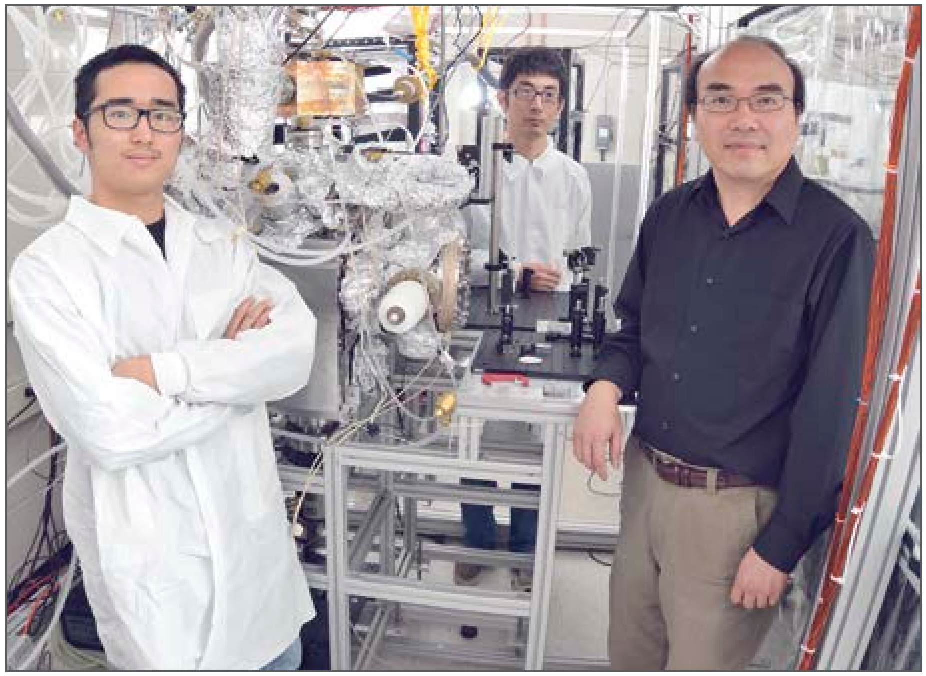
A semiconductor is a substance that conducts electricity under some conditions but not others, making it a good medium for the control of electrical current. The electrical properties of semiconductors depend on the nature of trace impurities, known as dopants, which when added appropriately to the material will allow for the design of more efficient solid-state electronics.

The MSU researchers found that by shooting an ultrafast laser pulse into the material, its properties would change as if it had been chemically "doped." This process is known as "photodoping."

"The material we studied is an unconventional semiconductor made of alternating atomically thin layers of metals and insulators," said Chong-Yu Ruan, professor of physics and astronomy who led the research effort at MSU. "This combination allows many unusual properties, including highly resistive and also superconducting behaviors to emerge, especially when 'doped.'"

An ultrafast electron-based imaging technique developed by Ruan and his team allowed the group to observe the changes in the materials. By varying the wavelengths and intensities of the laser pulses, the researchers were able to observe phases with different properties that are captured on the femtosecond timescale. A femtosecond is 1 quadrillionth—or 1 millionth of 1 billionth—of a second.

"The laser pulses act like dopants that temporarily weaken the glue that binds charges and ions together in the materials at a speed that is ultrafast and allows new electronic phases to spontaneously form to engineer new properties," Ruan said. "Capturing these processes in the act allows us to understand the physical nature of transformations at the most fundamental level."



(L to R): Faran Zhou, physics and astronomy doctoral student; Terry Han, who just earned his Ph.D. in physics and astronomy; and Chong-Yu Ruan, professor of physics and astronomy, are part of a team that developed an ultrafast microscope that allows researchers to view changes in materials caused by laser pulses.

". . . we envision working with engineers . . . to control how electrical signals propagate in a network at a high speed."

"Ultrafast photodoping has potential applications that could lead to the development of next-generation electronic materials and possibly optically controlled switching devices employing undoped semiconductor materials," said Phillip Duxbury, research team member and chairperson of the Department of Physics and Astronomy.

"Using our new high-brightness ultrafast electron beam system, we are now able to inspect the dynamics in more detail, especially regarding the long-range ordering change that has to happen for the electronic switching to complete its course," Ruan said. "This is like a domino effect where the initial changes, which occur on the local scale, can quickly propagate throughout the network, taking advantage of the intimate coupling between the active components at different sites. The large coherence length of the new electron beam system allows us to track these multi-scale ordering changes all at once with high fidelity."

"Based on these new results, we envision working with engineers to design a broad-band circuit that could be interfaced with the femtosecond photodoping to control how electrical signals propagate in a network at a high speed," Duxbury said. "Such strategy, if successful, may realize high-speed THz electronic devices in communications technologies and other high-speed applications."

Konrad Gelbke: A remarkable scientist, leader, mentor

When Konrad Gelbke secured a job in 1977 at MSU's National Superconducting Cyclotron Laboratory (NSCL), he planned to stay for a couple of years. Instead, he stayed for more than 35.

He earned his Ph.D. in physics at the University of Heidelberg in 1973, and then spent several years as a researcher at the Max Planck Institute for Nuclear Physics in Heidelberg and at the Lawrence Berkeley National Laboratory in California before joining NSCL as associate professor of physics. He was appointed director of NSCL in 1992 and served for 23 years before retiring earlier this year.

Konrad Gelbke

"Having Konrad as a mentor really helped me excel in my career field."

Gelbke is cited as one of the most influential individuals in bringing the Facility for Rare Isotope Beams (FRIB) to MSU. It was a long struggle, Gelbke noted.

"We had to build the science case for the facility we proposed," he said. "We did a lot of public education and worked hard in the science community. We always did this in the limelight of the public, not behind closed doors—so everyone could see what we thought was the right thing to do."

In recognition of his remarkable career and outstanding leadership, which brought the laboratory to where it is today, a scientific symposium was held in October in his honor, in conjunction with an NSCL 50-year-anniversary celebration.

One of the speakers was David Fields, Gelbke's second Ph.D. student at MSU, who is currently chief technology officer at Logos Technologies.

"I've been working with Konrad for nearly 30 years," Fields said. "While at MSU, I was enormously productive. I attribute this to Konrad's leadership." In four years, Fields published 28 scientific articles.

Another speaker was Gelbke's former postdoctoral research associate David Bowman, who is currently deputy associate administrator for the Department of Energy's (DOE) National Nuclear Security Administration.

"Having Konrad as a mentor really helped me excel in my career field," Bowman said. "The things I learned from Konrad about technical excellence and validating experimental measurements ring true—especially when doing applied work.

"I led the DOE teams that responded to the Fukushima emergency in Japan in 2011," Bowman continued. "Again, those of us who worked for Konrad know he was insistent on making technically sound measurements but getting results out quickly."

It's difficult to imagine Gelbke working in any other field, but early on, he wanted to be a physician. That is, until he watched his father perform a surgery one day.

"Next thing I remember, a nurse was standing over me, asking, 'Are you okay, Mr. Gelbke?' When my dad came home that day, he said to me, 'You're not going to be a doctor!'"

After 38 years in the field of experimental nuclear physics, Gelbke felt it was time to make a change.

"I decided to rebalance my life; I'm going to devote more time to family," said Gelbke, who stepped down from his directorship in May and moved to Montana.

Meanwhile, life goes on back at MSU, as the facility that Gelbke helped build transitions from NSCL and FRIB into the FRIB Laboratory.

"The FRIB Laboratory is in good hands; there is a phenomenal team there," Gelbke said. "It's time for me to get out of the way for the new leadership team. I'm predicting a brilliant future for the laboratory."

How stars are born

Why are some of the galaxies in our universe veritable star nurseries—while others are not? Our own Milky Way produces, on average, at least one new star every year. But others went barren years ago and are now producing few—if any—new stars.

An MSU-led team has discovered that galactic "rain" may be the key to whether a galaxy is fertile.

"We know that precipitation can slow us down on our way to work," said Mark Voit, professor of physics and astronomy and College of Natural Science associate dean for undergraduate studies, who led the research team. "Now we know it can also slow down star formation in galaxies with huge black holes."

Using NASA's Chandra X-ray Observatory, Voit's team analyzed X-rays from more than 200 galaxy clusters.

The central galaxies within these clusters are surrounded by enormous atmospheres of hot gas that normally would cool and form many stars. However, this is not what astronomers see.

"Something is limiting the rate at which those galaxies can turn gas into stars and planets," Voit said. "It looks like the hot gas produces a rain of cold clouds that feeds the huge black hole at the center of the galaxies, and the black hole's response slows down star formation."

"... precipitation can slow us down on our way to work ... now we know it can also slow down star formation."

Images from NASA's Hubble Space Telescope have allowed MSU astronomers to observe how that process works. Those images reveal brilliant knots of hot, blue stars forming along jets of matter propelled by active black holes found in the centers of these galaxies.

The Hubble study, led by Megan Donahue, professor of physics and astronomy, looked at far-ultraviolet light from a variety of massive elliptical galaxies found in the Cluster Lensing and Supernova Survey with Hubble, or CLASH, which contains elliptical galaxies in the distant universe. These included galaxies that are raining and forming stars, and others that are not. The ultraviolet pictures showed that the black holes, jets and newborn stars are all parts of a self-regulating cycle that controls the rate at which gas can cool and fall into a galaxy.

Together, these two studies explain the mystery of why many elliptical galaxies in the present-day universe are not ablaze with a higher rate of star birth. Theoretical models of galaxy evolution predict that present-day galaxies more massive than the Milky Way should be bursting with star formation, but that is not the case.

Now scientists understand this is simply arrested development, where a cycle of heating and cooling keeps star birth in check.

The researchers were aided by a new set of computer simulations of the hydrodynamics of the gas flows.

"These are the first simulations to show in detail how black-hole jets can trigger showers of star formation," Voit said. "And when we compare these new models to the Hubble data, there's a stunning similarity between the star-forming showers we observe and ones that occur in our simulations."

Mark Voit and Megan Donahue, MSU physics and astronomy researchers, collaborated to explain the mystery of why many elliptical galaxies in the present-day universe are not ablaze with a higher rate of star birth.

Collaborative research efforts promote physics learning

The Physics Education Research Lab (PERL) at Michigan State University is an interdisciplinary collaboration that studies how students learn physics and engage in physics practice.

"We look at social and contextual factors that promote student learning and engagement as well as conceptual learning, epistemology, and educational technology use and practice," explained Danny Caballero, assistant professor of physics and PERL co-director.

The lab supports work in a variety of contexts from pre-college to post-graduate. PERL includes faculty and staff members, postdocs and students from the MSU Department of Physics and Astronomy, the College of Education, Lyman Briggs College and the CREATE for STEM Institute.

Caballero came to MSU in 2013 to start the lab. At the time, he had one graduate student working with him. A year later, Vashti Sawtelle, an assistant professor of physics, joined him as co-director of PERL. Over the course of two-and-a-half years, six research associates, six graduate students and eight undergraduate students have joined PERL.

Through a variety of funding sources including the National Science Foundation and the Howard Hughes Medical Institute, numerous research projects are underway. One project focuses on computational modeling.

"It is critical for science and engineering students to develop skills using the modern tools of science and engineering," Caballero explained. "Students are going into a world where all the problems that could be solved with pencil and paper have been solved. What we look at is what modern problems they have to deal with and how can we help them learn the skills and tools to attack those problems."

One aspect of Sawtelle's work with PERL focuses on how to create learning environments that help students build connections between different science disciplines, such as biology, chemistry and physics.

"The problems scientists will be solving in the future will require expertise not just in a single discipline, but across disciplines and expertise that is adaptive to the situation," said Sawtelle, who also holds an appointment as an assistant professor in the Lyman Briggs College.

Another important aspect of this research is understanding the role that learning environments play in shaping the ways students see themselves as scientists.

"Science students are generally required to take coursework outside their chosen discipline," Sawtelle explained. "We look at how these non-major courses contribute to a student's developing sense of self as a scientist. In particular, we want to understand how students from traditionally underrepresented groups see themselves becoming scientists."

For more information on PERL, visit http://www.perl.pa.msu.edu.

MSU marks special cyclotron beam anniversary

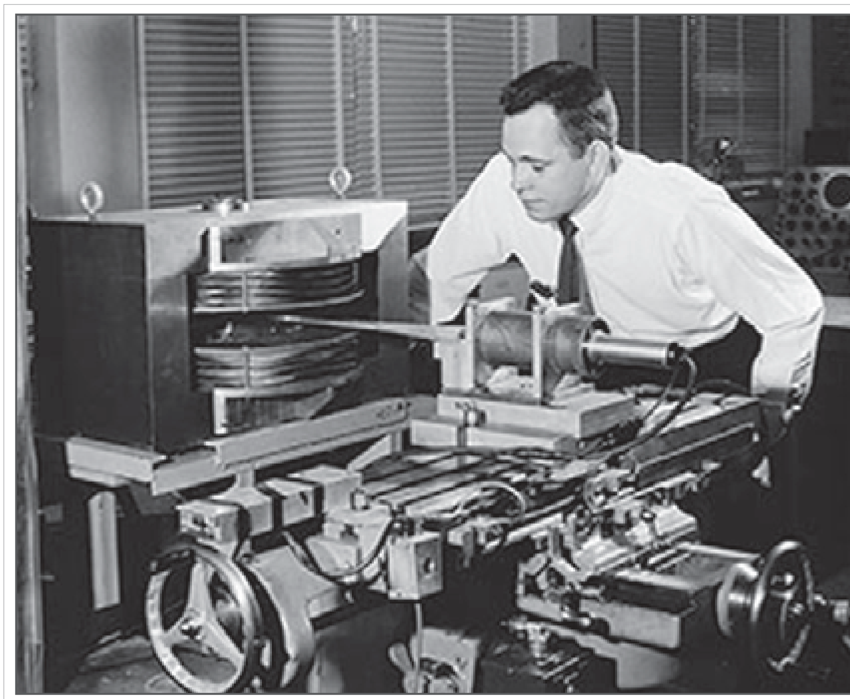
It was 50 years ago that the National Superconducting Cyclotron Laboratory at Michigan State University accelerated its first beam and the university and the scientific world haven't been the same since.

Known as the K50 cyclotron, the acceleration of its first beam launched an MSU tradition not only of nuclear physics academic excellence, but one of visionary anticipation and response to the rapidly advancing frontiers of nuclear science.

The K50 soon evolved into the more-powerful K500 and K1200. Today, MSU is the site of the under-construction Facility for Rare Isotope Beams, which, when completed, will be the gold standard for rare-isotope research.

Scheduled for completion in June 2022, FRIB will be the most powerful facility of its kind, hosting researchers from around the world who will conduct experiments, extend the frontiers of nuclear science, and help define what the next frontiers are.

For information about FRIB, visit www.frib.msu.edu.



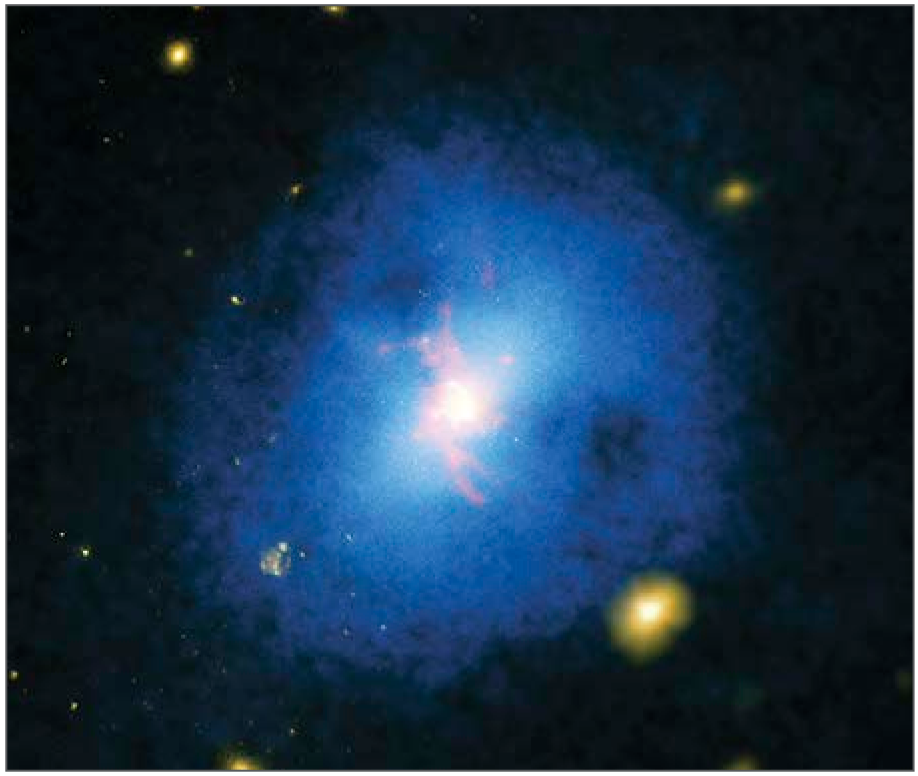
Henry Blosser, founding director of the National Superconducting Cyclotron at MSU, inspects a model magnet used in the first cyclotron—the K50.

We're not alone—but universe may be less crowded than thought

There may be far fewer galaxies further out in the universe than might be expected, according to a new study led by Michigan State University.

Over the years, the Hubble Space Telescope has allowed astronomers to look deep into the universe. The long view stirred theories of untold thousands of distant, faint galaxies. The new research, however, offers a theory that reduces the estimated number of the most distant galaxies by 10 to 100 times.

"Our work suggests that there are far fewer faint galaxies than we once previously thought," said Brian O'Shea, MSU associate professor of physics and astronomy. "Earlier estimates placed the number of faint galaxies in the early universe to be hundreds or thousands of times larger than the few bright galaxies that we can actually see with the Hubble Space Telescope. We now think that number could be closer to ten times larger."



There may be far fewer galaxies further out in the universe than might be expected, according to a new study led by MSU.

"The Hubble Space Telescope can see the tip of the iceberg of the most-distant galaxies."

O'Shea and his research team used the National Science Foundation's Blue Waters supercomputer to run simulations to examine the formation of galaxies in the early universe. The team simulated thousands of galaxies at a time, including the galaxies' interactions through gravity or radiation.

The simulated galaxies were consistent with observed distant galaxies at the bright end of the distribution—in other words, those that have been discovered and confirmed. The simulations didn't, however, reveal an exponentially growing number of faint galaxies, as has been previously predicted.

"The number of those at the lower end of the brightness distribution was flat rather than increasing sharply," added O'Shea, who also holds joint appointments in the MSU Department of Computational Mathematics, Science and Engineering, and the National Superconducting Cyclotron Laboratory.

These simulations will be tested further when the much-anticipated James Webb Space Telescope comes online in late 2018. The improved technology will afford astronomers even more-detailed views of space than the amazing images that the Hubble has produced in recent years.

"The Hubble Space Telescope can see the tip of the iceberg of the most-distant galaxies," said Michael Norman, co-author of the paper and director of the San Diego Supercomputer Center at the University of California, San Diego.

While the James Webb telescope will improve views of distant galaxies, the telescope has a relatively small field of view. As a result, the observations must take into account cosmic variance—the statistical variation in the number of galaxies from place to place.

"That's what makes these simulations pertinent even as improved technology becomes available," O'Shea said. "A deeper understanding based on theory may be necessary to correctly interpret what's being seen, such as high redshift survey results."

In addition to O'Shea and Norman, the research team also included John Wise, an assistant professor at the Georgia Institute of Technology, and Hao Xu, a postdoctoral research associate at the University of California, San Diego. The research is funded by the National Science Foundation and NASA.

MSU key collaborator in HAWC observatory research

MSU researchers have played a key role in the High-Altitude Water Cherenkov (HAWC) Gamma-Ray Observatory, which studies high-energy gamma rays and cosmic rays coming from extreme sources in the universe, such as evaporating black holes, dark matter annihilation or decay and exploding stars. HAWC enables scientists to visualize these explosive events and learn more about the nature of high-energy radiation.

The facility, located 13,500 feet above sea level near Puebla, Mexico, became fully operational in March. MSU is one of 14 U.S. and 10 Mexican universities in the collaboration.

“. . . we’re answering the really big questions about how the universe was formed and what the future of the universe is.”

HAWC has capabilities for detecting the highest-energy electromagnetic radiation, and complements other gamma-ray observatories around the world. It is expected to be 10-15 times more sensitive than its predecessor, the Milagro experiment in Los Alamos, and will continuously monitor a wide field of view to observe two-thirds of the sky every 24 hours.

MSU researchers are playing key roles in the new High-Altitude Water Cherenkov Gamma-Ray Observatory. Located in Mexico, HAWC is a collaboration between the United States and Mexico.

“This survey instrument enables us to get an unbiased view of the sky in very high-energy light,” said Jim Linnemann, MSU physics and astronomy professor and HAWC electronics coordinator. “It allows us to look at unusual and exotic sources, like gamma ray bursts, which we might see only twice a year.”

Each of HAWC’s detectors is a huge tank containing 50,000 gallons of ultrapure water with four light sensors anchored to the floor. With 300 detectors spread over an area about the size of three football fields, HAWC is able to “see” these events in relatively high resolution. Surrounding this main array, 350 smaller tanks were added this summer.

“In our field of astroparticle physics, we’re answering the really big questions about how the universe was formed, and what the future of the universe is,” said Kirsten Tollefson, MSU physics and astronomy associate professor and deputy manager of HAWC detector operations. “Is our ultimate fate going to be a big crunch or the big freeze? Will we expand forever or collapse back in on ourselves?”

“HAWC recently made a significant improvement in its sensitivity due to software improvements that double its spatial resolution,” Linnemann said. “In addition, the energy estimation software developed by our group—especially graduate student Sam Marinelli—is now being integrated into HAWC software. It measures energy over a factor of two times more accurately than the measures previously used.

“We found a way in which our search for primordial black hole explosions could also possibly be sensitive to production of high-mass supersymmetric scalar quarks (squarks),” Linnemann noted. “The actual search analysis has started. We hope to start seeing more new sources when data is re-analyzed with these and other improvements.”

Tyce DeYoung, MSU physics and astronomy associate professor, is also involved part-time with the facility.

The National Science Foundation, the U.S. Department of Energy and the Los Alamos National Laboratory provided funding for the United States’ participation in the HAWC project. El Consejo Nacional de Ciencia y Tecnología is the primary funder for Mexican participation.

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Seeing triple: New 3-D model could solve supernova mystery

Giant stars die a violent death. After a life of several million years, they collapse into themselves and then explode in what is known as a supernova.

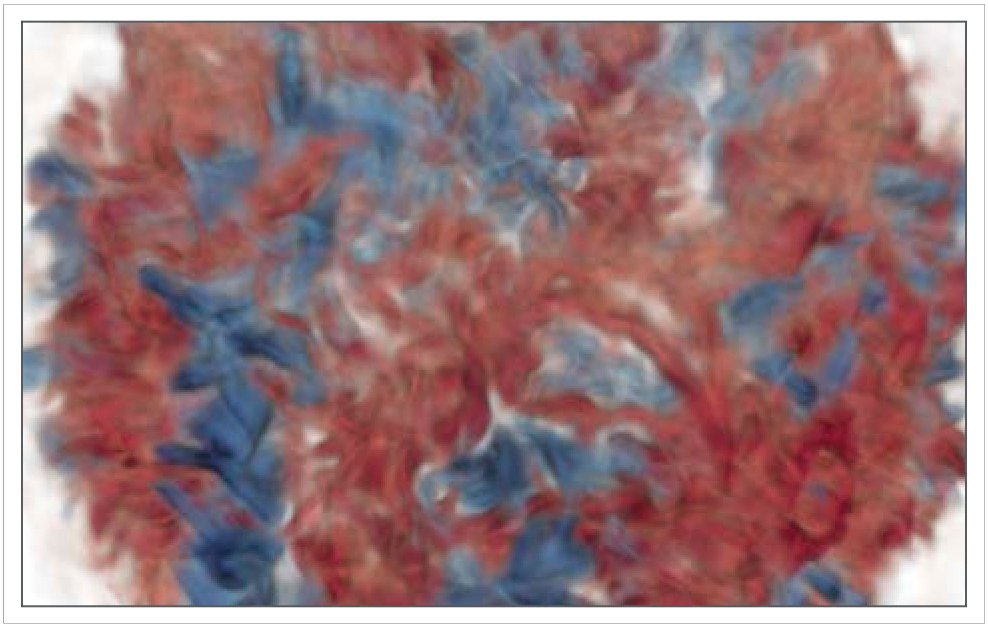
How these stars explode remains a mystery. However, a research team led by Michigan State University developed a 3-D model of a giant star's last moments.

"This is something that has never been done before," said Sean Couch, an MSU assistant professor of physics and astronomy and a member of the research team. "This is a significant step toward understanding how these stars blow up."

Until now, researchers have been able to do this only in one-dimension. Nature, of course, is three-dimensional. What allowed the researchers to break the 3-D barrier is new developments in technology, including both hardware and software innovations.

Until now, computer models did not match what was observed in the real world.

"We just couldn't get the darn things to blow up," Couch said. "And that was a problem because that's what happens in nature. It was telling us that we were missing something."



The final seconds in the life of a very massive star are captured in 3-D by an MSU-led team of scientists.

The other problem the 3-D model addresses is the actual shape of the star. Older computer models yielded stars that were perfectly spherical. However, that is not what real stars look like. This new work shows that the messy details matter for understanding supernova explosions.

The development of the 3-D model is an early step in pinning down the reasons why stars explode and could completely change the way scientists approach the supernova mechanism.

Other members of the research team are Emmanouil Chatzopoulos (University of Chicago), W. David Arnett (University of Arizona) and F.X. Timmes (Arizona State University).