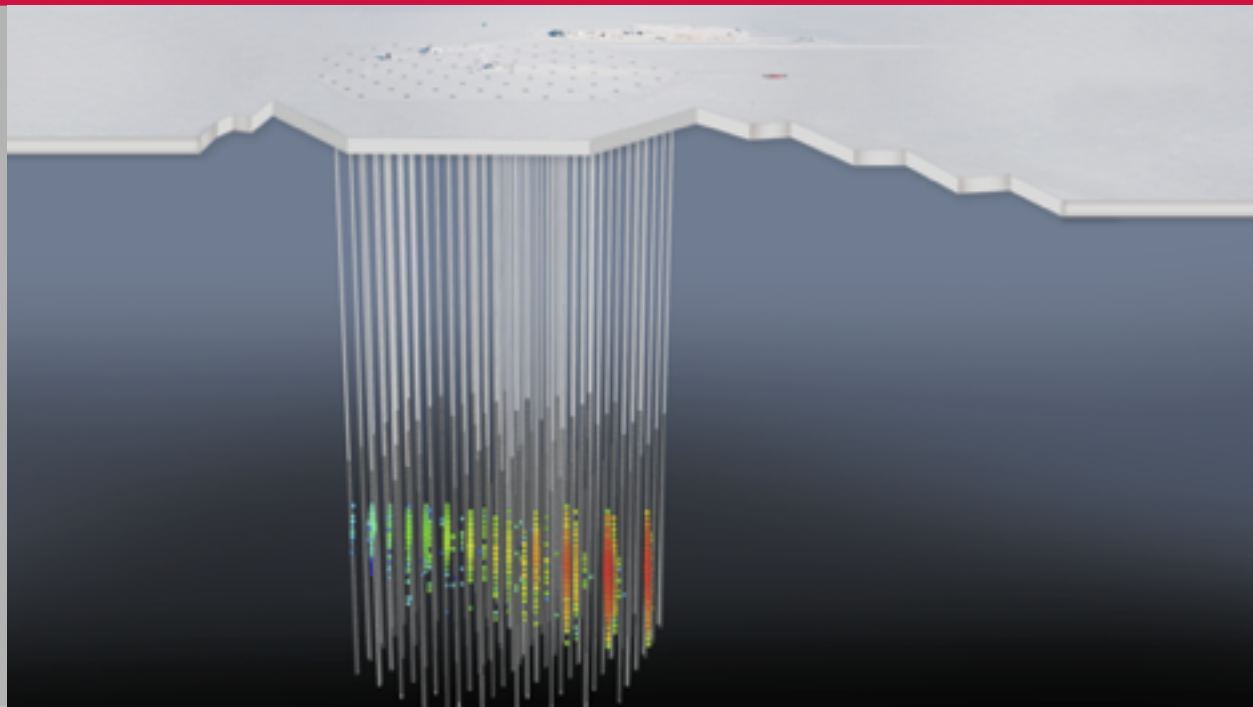

The Wisconsin Physicist



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On the Cover

The TXS 0506+056 event as seen by the IceCube detector

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Greetings from the Chair



Dear Alumni and Friends

The Physics Department continues to be a vibrant place for education, research and outreach in a wide range of areas. This new edition of the Wisconsin Physicist will give you an opportunity to get a glimpse of our department in 2018.

I would like to begin by introducing to you the administrative team for the year comprising of Associate Chair, Professor Mark Rzchowski, Associate Chair for Alumni Affairs, Professor Robert Joynt, Department Administrator Ms. Aimee Lefkow, Director of Graduate Studies, Dr. Jeffrey Schmidt and Director of Undergraduate Studies, Dr. James Reardon. This somewhat modified organizational structure is a continuation of the devolution of duties and responsibilities to increase our effectiveness. We also welcomed Ms. Michelle

Holland as a Graduate Student Coordinator. We all share the goal of sustaining the best practices in the department and improve wherever possible.

We were fortunate to welcome wonderful new faculty Assistant Professor Keith Bechtol, Associate Professor Brian Rebel, Professor Kevin Black and Professor Tulika Bose in September 2018. You will be pleased to read about their recent accomplishments that caught our attention and the promise they hold for the continued success of the department's mission in research, teaching and service to the University and beyond.

My colleague and mentor, Professor Wesley H. Smith, retired effective Fall 2018 after a very successful career in Experimental Particle Physics and teaching on our campus. He is the world-expert in building high-speed digital electronics systems for high-energy physics applications. His research team, including myself, has delivered the trigger electronics for the ZEUS experiment in DESY, Hamburg and the CMS experiment at CERN, Geneva. At ZEUS, Professor Smith and his students mapped out the details of proton structure, which provided necessary precise measurements to bolster QCD as the theory of strong interactions, and technical information to predict rates of production of high-energy processes, seen in proton-proton colliders such as the LHC. The trigger systems built for the CMS experiment under Professor Smith's leadership were pivotal in the discovery of the Higgs boson at the LHC and all other measurements being made there. The department is organizing a WesleyFest on August 30-31, 2019 to celebrate Professor Wesley Smith's unparalleled contributions to experimental particle physics.

Professor Michael Winokur who is a well-known experimental condensed matter physicist and a mentor of undergraduate students in our department, has also retired effective Fall 2018. Professor Winokur helped define the careers of our undergraduate physics majors, recruiting them and guiding them in selecting appropriate physics learning program and honing their skills for graduate studies or careers in industry. Professor Winokur also helped with the departmental outreach by participation in Wonders of Physics and the Ingersoll Museum.

The department mourned the untimely death of Professor Stefan Westerhoff, who was a beloved faculty member teaching core courses to our undergraduate students, guiding several graduate students in Astrophysics and a leader on the HAWC high-energy gamma-ray observatory in Mexico and the IceCube high-energy neutrino observatory at the South Pole. The department is hosting Professor Stefan Westerhoff memorial colloquium and chamber music concert on April 5, 2019, to celebrate his scientific contributions and love of classical music.

The department received a very pleasant surprise in terms of an unexpected gift valued at about \$3M, the largest in the department history, from Mr. Ray MacDonald, a former Masters graduate of the department and a returning student with immense love for physics, mathematics and astronomy. The gift is setup as an endowment, which will be used in perpetuity to support the full mission of the department: research, teaching and service to community at large.

Greetings from the Chair

The department also received a gift which resulted in the setting up of Martin L Perl professorship in physics, following the guidance of the donor. A search is currently underway for a candidate to fill Perl professorship in the area of ultrafast science exploiting X-ray free electron lasers and related technologies to study physical phenomena.

The department also won the campus wide cluster hiring competition which resulted in a search for a senior faculty member in the area of Quantum Information. The department also hopes to welcome a new faculty member as part of the Target of Opportunity program launched by the Provost's office.

Graduate student recruitment for 2018, with the help of current graduate students, has gone very well resulting in the most diverse class ever. The graduate students have formed a new association to improve their well-being and success in the department.

The department celebrated the 100th anniversary of its Ingersoll Museum in 2018. Prof. Robert Joynt unearthed interesting history of the museum, which it appears is the second oldest such touch-me museums in the world, and the only one continuously in operation for the past 100 years. The celebration in January marked a lecture by Professor Joynt on the history of the museum and other important contributions by UW faculty prior to the World Wars. Dr. Jim Reardon spoke about the first public radio transmissions using vacuum tubes developed in the department. The replica reconstructed for the 100th anniversary celebration of the Wisconsin Public Radio was also featured in the department for the Ingersoll Museum anniversary.

The 17th Annual Awards Banquet was held in May 4th, 2018. The continued generosity of our alumni and friends allows us to present many awards to outstanding students. You can read more about the Awards Banquet on p. 17. We are pleased to maintain our tradition to recognize Distinguished Alumni. The department honored Janet Seger and Michael Zarnstorff with awards.

The Physics Department Board of Visitors met once in 2018. The Board of Visitors continues to help us in a number of ways, by providing feedback to the Department, recruiting of graduate students, and last, but not the least, with fundraising. Of particular note this year is the beginning of a new initiative to fund the first gift funded professorship in the name of Prof. Bernice Durand. Prof. Durand served the University in various capacities and was a well-liked and recognized teacher especially noted for promoting Physics 107, The Ideas of Modern Physics.

Whether you are an alum, friend, employee, or student, we appreciate your interest in, and loyalty to, the University of Wisconsin-Madison Physics Department. All of our awards are funded by generous donations. As an example Physics Alumni Graduate Support Fund, allows us to give fellowships and supplement the stipends of incoming graduate students. Donations also help in other ways, for instance, in supplementation of the Ingersoll museum operations. You can donate to the Physics Department online by going to <http://www.physics.wisc.edu/giving>. Please see page 24 for more ways to give.

I sincerely thank our generous alumni and friends who have financially supported the Department. This support is truly our margin of excellence.

Sridhara Dasu - Department Chair

100 Years of the Physics Museum



L.R. Ingersoll

by Robert Joynt

This year marks the centennial of the Ingersoll Physics Museum. The department put on a very successful celebration event on January 26, with a reception, tours and a presentation describing the history of the museum and the history of the department in the time around World War I.

I was assigned the task of researching the history and discovered, somewhat (but not entirely) to my surprise, that the museum has considerable historical significance. This article will tell you why.

The museum was founded in 1918 by Professor Leonard Rose Ingersoll (1880-1958). Ingersoll arrived in Madison in 1902 and advanced from Instructor in 1905 to Professor in 1925. He was Department Chair from 1936-1947 and retired in 1950. He researched the thermal, optical and magnetic properties of materials, work that continues today in the department. His greatest achievements were in the area of high-precision measurements of the Faraday effect in gases.

His name lives on in Chamberlin Hall in the L.R. Ingersoll Museum. The museum started life as the “The Physical Museum of the University of Wisconsin” and was renamed after his death in 1958.

The department adopted a mission statement for the museum in 2016 that it is to:

1. Promote Understanding of Science;
2. Encourage Budding Scientists;
3. Showcase the Research Work of the Department.

Only number 3 is different from Ingersoll’s original vision, which also included regular instruction of classes in the museum, which is no longer done. (Actually, we’re still working on number 3.)

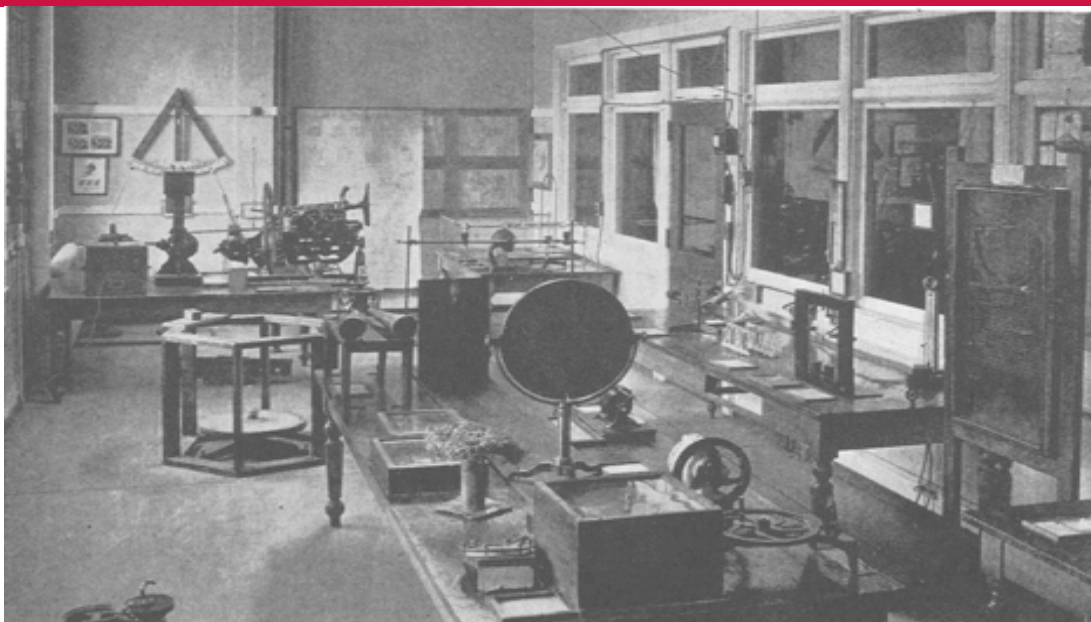
The museum gets more than 5000 visitors per year. It has never had a regular budget from the state or the university, and it runs on small donations and volunteers. It’s a great asset for the department, the university, and the state. However, it has a different significance for me. I was impressed from my first acquaintance with the museum in 1986 that many, in fact almost all, of the exhibits are “hands-on”. This is a great way to present science, of course, and the popularity of our museum, especially with kids, has always depended on this. But I seemed to recall that various large science museums built starting in the 60s bragged about this innovative new kind of exhibit. Of course by that time the Ingersoll Museum had already been open for 50 years or so. When the centennial rolled around, it was a great opportunity to do a little research and find out whether Ingersoll started the whole interactive exhibit thing.

One issue was settled right away. Ingersoll from the very beginning meant his museum to be what we now call “hands-on”. Here are his words from 1936 in an article in *The American Physics Teacher*.

Of much greater interest, however, are the experiments that “work”. These vary in complexity from the cut-away push-button-operated Ford motor, transmission, and differential, to the simple air pressure experiments shown in Fig. 2 (left). The conservation-of-angular-momentum platform (Fig.1, left center) is always a center of interest. Some good modifications of the usual demonstrations-including the principle of the gyrocompass – can be shown when a weighted bicycle wheel is used in connection with this turntable.

Fig. 2 is reproduced below. Those who saw the museum in Sterling Hall will recognize the Ingersoll Museum immediately. It did not change all that much until the move to Chamberlin Hall in 2005 (to a much larger and better room). The conservation-of-angular-momentum platform is still a center of interest. Ingersoll also wrote a shorter article in *Science* in 1921 with much the same description. It is very clear that the interactive exhibits were not a later addition, and date all the way back to 1918.

100 Years of the Physics Museum



The Physical Museum of the University of Wisconsin, 1936

1913 that describes the exhibition hall:

“Prof. (Eugen) Goldstein had the happy thought to design the exhibits so that the members of the public could experiment for themselves. In this way the dead character of the museum was changed and in the Urania a new path was created for autodidactic learning.”

Below is a picture of the Urania from that time – a reminder of the wonders of Germany just before it plunged into disaster. This building was in Taubenstrasse in the very center of Berlin in 1913 and the street is still there, though the building is not. It was destroyed by bombs in February 1945. Taubenstrasse is a short street and



Die Urania in Berlin, Taubenstrasse.

The Urania

the main attraction is the Newton Bar, so some of the scientific spirit perhaps remains.

So Ingersoll was not quite the first to design exhibits that “work”. It seems quite likely that he invented many new exhibits. But is the Ingersoll Museum the first interactive science museum in the Western Hemisphere? The first mention of such a museum in the Americas but outside Madison that I can find is the Museum of Science and Industry in Chicago. Julius Rosenwald, the president of Sears, donated 3 million dollars in 1933 to start MSI and specified that it should include interactive exhibits, and he explicitly mentioned the example of the Urania. The most venerable of all science museums in the United States is the Franklin Institute in Philadelphia, founded in 1824. But it added interactive exhibits only in 1934. The Exploratorium in San Francisco, explicitly themed to be interactive, opened in 1969. I have not been able to find any museum in the Americas, and indeed none in the Old World apart from the Urania, that had exhibits of this kind prior to the 1930s.

So Germany was first in the world, but Ingersoll was first in the US. Not only that, but it seems nearly certain that that oldest interactive science museum in continuous operation in the world is the one in Chamberlin Hall.

But did Ingersoll actually invent this type of exhibit? There is a clue in his *Science* article in which he mentions his inspiration for the museum as being the Urania in Berlin. The Urania was founded in 1888 as a society for the communication of science to the public. It still exists, though not as a museum. On its website is an anonymous report from

Endowed Chair



by Lloyd Hackel

The Physics Department Board of Visitors has set up a fund for alumni and friends to step forward and take on the challenge to endow a faculty chair. The endowed chair is to be named after our own highly recognized and respected Emeritus Professor Bernice Durand.

An endowed professorship aids the University and Department by providing a permanent funding source that supports a faculty member who does not have to be paid entirely out of the limited state operating budget. It allows the Department to attract and retain the highest level of scientist, reduces the student-to-faculty ratio, and because our physics faculty are so very effective in securing research funds, the endowed chair will almost assuredly generate, each and every year, funding for multiple graduate students as well as educational opportunities for undergraduates. An increased demand for physics education has resulted from the renewed

emphasis on STEM education. This demand spans the range of guiding students through highly specialized advanced degree programs to teaching the foundational service courses for students pursuing degrees outside of physics. Emeritus Professor Bernice Durand has exemplified the role of a gifted researcher and devoted teacher inspiring physics and non-physics majors across the University.

With state support shrinking more and more it becomes the role of alumni and friends to recognize a debt we owe for our education and to help provide critical educational support for continued generations. Our goal is to fund the chair within the upcoming year. We recognize \$2M is a large amount but with your support, we can and will get there.

Emeritus Professor Bernice Durand has been a gifted educator within the Department and reached out far beyond to the University, the community and the State. We feel that it is most fitting to name the chair in her honor.

Donating to the fund is easy on line at:

<https://secure.supportuw.org/give/?id=a0e1d941-6b49-4710-a5fa-e9a2abdb8efa&>

The endowed chair name and number are:

Physics Board of Visitors' Endowed Chair Fund - # 132540056

Because an endowed chair will continue year after year, gifts will keep on giving both to the Department and to students who will greatly benefit from the educational experience and the secondary financial support the chair generates.

Keith Bechtol



by Peter Timbie

Assistant Professor Keith Bechtol joined us this fall to expand the Department's program in observational cosmology and particle astrophysics. His request to the Physics Facilities Committee was quite immodest - - for lab space he requires the entire cosmos! On the largest scales, he studies the distribution of galaxies to learn about dark energy, the mysterious anti-gravity agent that is causing the expansion of the universe to accelerate, and about inflation, neutrino mass, etc. On smaller scales he studies some of the small-scale objects sprinkled throughout the universe to learn about dark matter, the origins of the highest-energy cosmic rays, etc.

Keith comes most recently from the University of Arizona, Tucson, where he was the Project Commissioning Science Validation Lead for the Large Synoptic Survey Telescope (LSST) and a member of the LSST Dark Energy Science Collaboration. He continues in those roles at UW. LSST, now under construction in Chile with first light

expected in 2020, will catalog more stars and galaxies than all previous astronomical surveys combined. In an area covering half the celestial sphere, every spot will be imaged nearly 1000 times over 10 years across 6 color filters. His group will help to commission the telescope, camera, and data management system, and do science with this incredibly rich dataset.

Keith and collaborators recently discovered small galaxies orbiting the Milky Way that have more than 1000 times more dark matter than baryonic matter. These galaxies contain only a few hundred stars, barely enough to register in the Dark Energy Camera used for the Dark Energy Survey (DES), of which he is a team member. These dwarf galaxies are excellent systems for studying the nature of dark matter. In particular, Keith has used NASA's Fermi-LAT gamma ray telescope to constrain the dark matter annihilation signal from gamma rays from these systems.

Besides looking for faint dwarf galaxies, Keith is using both the DES and LSST to study the large-scale structure of the universe. As the Universe's expansion rate has accelerated under the influence of dark energy, the spatial clustering of galaxies has changed. In addition, gravitational lensing of distant galaxies by intervening matter distorts the apparent shapes of the galaxies and provides additional constraints on dark energy and dark matter.

Although originally from the Washington, DC area, Keith arrives with his small family as no stranger to Madison or the Midwest. He has been a postdoctoral fellow at the Kavli Institute for Cosmological Physics at the University of Chicago and a Bahcall Fellow at WIPAC. His graduate work was at Stanford, where he worked on the Fermi gamma-ray satellite.

As he sets up his lab and organizes his growing research group, he has jumped into teaching (with Matt Herndon) Physics 249, the third semester of our introductory sequence for physics majors.

Keith has lots of other interests too. He placed first (out of 8,000) in the Chicago Half Marathon 2014!

Kevin Black



by Sridhara Dasu

Kevin Black joined us as a Full Professor in Fall 2018. Kevin came to us from Boston University, where he is a well-known leader in the area of high-energy physics working on the ATLAS experiment on the LHC at the CERN laboratory in Geneva, Switzerland. He has an impressively large breadth of engagement covering all aspects of high energy experiments from detector construction to electronics, culminating in final analyses, which result in physics discoveries and publications. Having obtained a Ph.D. working on the D0 experiment at the Tevatron in Fermilab, IL, he moved on to the LHC program as a postdoctoral fellow at Harvard, where he helped build the muon detectors for the ATLAS experiment. He soon established himself as a prominent data analyst, producing new measurements of various Standard Model processes at the highest

energies. As the data accumulated in Run-1, he played an essential role in the Higgs Boson discovery by the ATLAS experiment. Since then, Prof. Black has focused on measuring processes involving top quark and the Higgs boson in the Run-2 of LHC which started in 2015. Prof. Black is also engaged in the design of electronics for the muon systems to upgrade ATLAS experiment for the high-luminosity operation phase of the LHC. He is planning to transfer that expertise to the CMS experiment muon system when in Madison.

Prof. Black held several leadership positions in the management of the ATLAS experiment collaboration, which includes about 3,000 scientists. Through physics analysis related leadership positions, he was responsible for muon trigger, reconstruction and performance, dilepton analyses resulting in early physics publications and searches for exotic new physics processes. Through computing related leadership positions, he continues to be responsible for enabling physics analysis resources for the US or world-wide community on ATLAS. He currently also holds the responsibility for designing a muon trigger upgrade for future operations of the LHC. Over the years, Prof. Black was called upon by his collaboration senior leadership, to provide counsel by participating in, or chairing various task forces assembled to tackle specific issues. Prof. Black joins the CMS research program at Wisconsin to bring those leadership abilities and technical skills.

Prof. Black's outstanding teaching record includes extensive instruction in the undergraduate curriculum of Boston University. He was also deeply engaged in the undergraduate research mentorship at BU. At Boston University, Prof. Black also served as the director of their graduate program. Prof. Black was research director for the BU physics department research abroad program, which offers a research experience, focused study opportunities at the University of Geneva, Switzerland and CERN. Also Prof. Black managed, along with Prof. Tulika Bose, the Boston University physics outreach program for high school women and underrepresented minorities offering laboratory research opportunities for those students. We are looking forward to Prof. Black bringing to UW-Madison some of these new ideas for student research opportunities.

Tulika Bose

by Sridhara Dasu



Tulika Bose joined us as a Full Professor in Fall 2018. She comes from Boston University where she served an Associate Professor. She is a world-renowned experimental physicist whose work is in the area of high-energy physics. Bose honed her skills while working as a student and postdoc on the D0 experiment at the Fermilab, Illinois, and has enjoyed a meteoric rise to the highest levels of the CMS experiment at the LHC at the CERN laboratory in Geneva, Switzerland, where she now serves as the CMS Physics co-coordinator. She played leading part in the CMS experiment, which discovered the Higgs Boson, completing the Standard Model of particle physics, made precise measurements of multi-boson production mechanism to better understand the details of the Standard Model, and looked for new physics beyond the Standard Model, searching for resonances in di-boson spectra and new forms of matter like the vector-like quarks. Prof. Bose has been leading and making significant contributions to important searches for new heavy particles, producing several seminal new results using the CMS data. As the physics co-coordinator of the CMS experiment, consisting of almost 2000 physicists, she is responsible for all its physics output and has

the primary responsibility for determining the research directions of the collaboration.

Prof. Bose is a leader in the areas of trigger and data acquisition systems, which enable searches for new physics processes at proton-proton colliders. The CMS experiment observes about a billion collisions per second using hundreds of million active detector elements. The resulting data stream must be analyzed using custom electronics first to make a sub-selection, which is then analyzed in greater depth using generic off-the-shelf computing elements, to make decisions to store about a thousand events per second. The key physicist goal for these systems is to reduce the rate of interactions while holding the efficiency for storing rare high-energy processes high. The task requires the hardware, firmware and software skills of a good engineering team and a comprehensive knowledge of particle physics. Prof. Bose led a team of engineers, students and postdocs from Boston University and elsewhere on CMS. She was responsible for the software systems that triggered the data acquisition system of the CMS experiment. Her work was crucial for the discoveries made by the CMS collaboration. Prof. Bose is currently engaged in the design of electronics for the trigger systems to upgrade the CMS experiment capabilities for the high-luminosity operation phase of the LHC.

Prof. Bose is known as a very good teacher at Boston University and has mentored an excellent set of students and postdoctoral fellows. She has an extensive outreach program including important aspects on the diversity front. Through CMS and Boston University outreach programs she has engaged the broader community. Our department welcomes her to the UW-Madison faculty with plans to bolster our engagement with the broader community.

Brian Rebel



by Sridhara Dasu

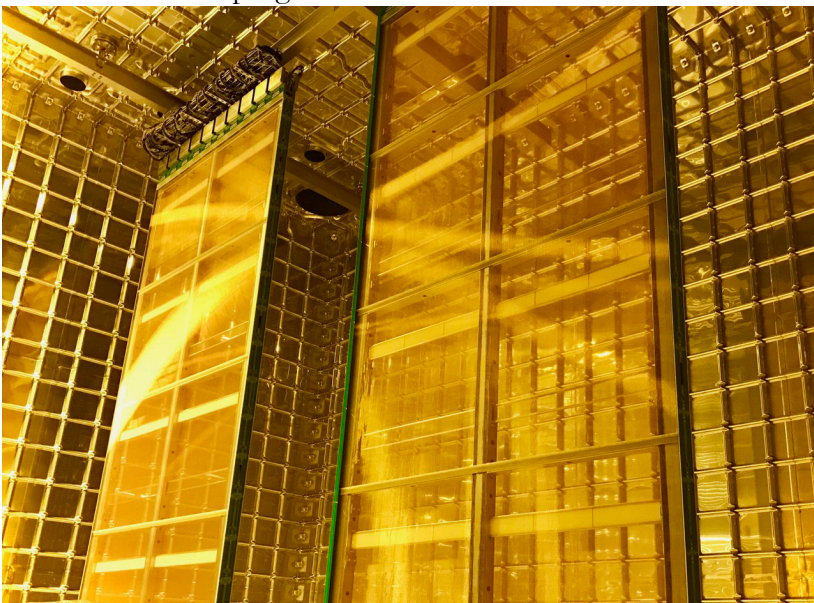
Brian Rebel joined us as an Associate Professor in Fall 2018. Brian is foremost amongst the experimentalists best positioned for making discoveries in the field of accelerator-based experimental neutrino physics. Brian brings us his unique experience from Fermi National Accelerator Laboratory.

Brian's appointment as Associate Professor was the result of a Strategic Plan of the Department of Physics. In a thorough strategic planning exercise with a forty-page document, the field of accelerator-based neutrino physics was defined as the top priority. The Department of Energy has decided to prioritize and engage on a two-billion-dollar program, the Long-Baseline Neutrino facility (LBNF), which will be based on a neutrino source at Fermilab and distant detector at the Sanford Lab in South Dakota. The proximity of Fermilab to Madison and the fact that the Physical Sciences Lab (PSL) in Stoughton is already involved in

early LBNF work and is well positioned to be heavily involved in the project, speak to the strategic importance of our department playing a strong role in LBNF.

Brian has established himself as a leader in the Deep Underground Neutrino Experiment (DUNE) Science program. He has extensive experience developing the new detection technology that will be employed in the DUNE experiment, having been an early proponent of that technology. With Brian we have the opportunity to rebuild our partnership with Fermilab and leverage our unique resources at PSL.

Brian is also a leader in the current generation of long-baseline neutrino science. That program is based on the existing neutrino beam at Fermilab that sends neutrinos through the Earth to the flagship US neutrino experiment, NOVA, in northern Minnesota. Upcoming results from the current generation of neutrino detectors will begin to inform us about the mass ordering of the three active neutrinos, and possibly about the magnitude, or feasibility for measurement of matter-antimatter asymmetry in the neutrino sector, which is the main goal of the future DUNE program.



On the left: APA (Anode Plan Assembly)s built by PSL that are installed in Proto DUNE

Ray Mac Donald



MS in Physics, 1975, MS in Nuclear Engineering, 1977

The department mourns the passing of Ray Mac Donald. After his graduation Ray began his career at ETA Inc. in Oakbrook, Illinois. He moved back to Madison and worked for Prof. Rock Mackie at TomoTherapy, Inc., a very successful local start-up that is now part of Accuray. He is remembered by Rock as a genial and helpful fellow who helped the company a lot in the early days. He also worked as a senior staff analyst at Compuware Corporation, CPU Incorporated, and the Lunar Corporation.

After his retirement, Ray returned to the department as a student. He audited courses in Physics and Astronomy for over 10 years. He was a quiet man, but remembered as a responsible and pleasant presence in the department with a wide range of interests, strong intellectual curiosity, and a love for science.

Prof Dan Chung, who taught several courses which Ray Mac Donald took said: *“I had the great privilege of lecturing to Ray Mac Donald in my physics 717 class (General Relativity) during the Spring semesters of 2018 and 2009. The fact that he completed 32 credits during his retirement years attests to his passion for learning. The seriousness with which he pursued knowledge can be seen, for example, from his desire to take 717 from me twice. He told me that taking 717 from me the first time inspired him to learn more mathematics (which he succeeded in doing by taking two graduate math courses in real analysis) before taking 717 again to learn general relativity more deeply.*

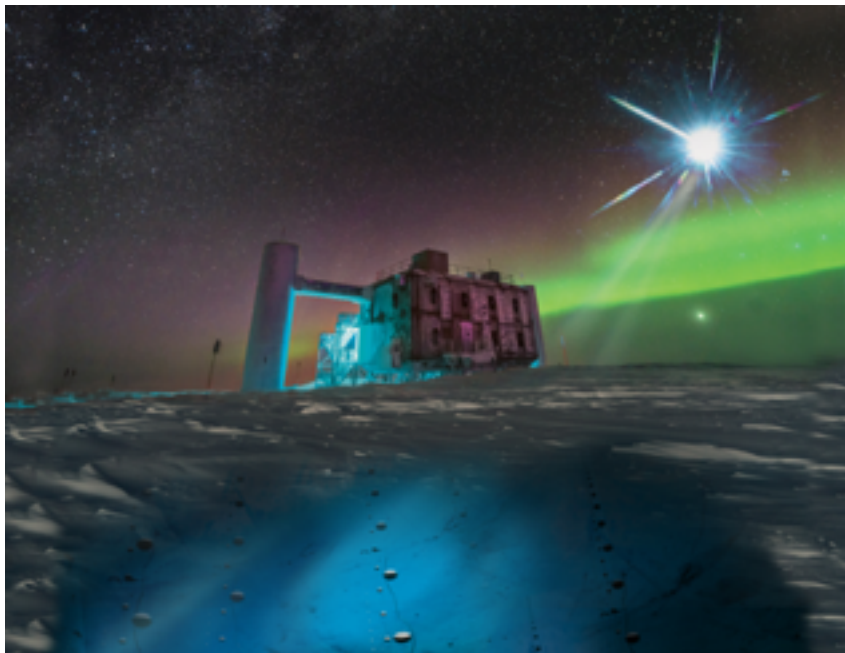
He was always punctual to lectures and followed my lectures attentively. His generous and kind nature was obvious as he often gave encouraging words to undergraduates before the lecture. Perhaps as a way of encouraging me, he often thanked me after lectures for explaining some of the seemingly impenetrable story behind the terse words of Robert Wald in the textbook GENERAL RELATIVITY. He would even offer to erase the whiteboard for me after the lectures. I also recall his offer to donate his extra books to undergraduates.”

Ray left his entire estate to the Physics Department. It is the largest single gift that the department has ever received. The Department has established an endowed fund from the proceeds, to be named the Ray Mac Donald Fund for Excellence in Physics. It will fund major projects in research, education, and outreach. The projects will be determined each year by a special committee.

Here is a statement from his classmate, Alec Hryciuk:

“Simple questions. Often we learn the most from asking the simplest of questions. A learning for the asker awaiting an answer, and also the one being asked. Ray MacDonald was a master of simple questions. I met Ray in one of my classes, where we both shared seats in the front row. I remember the first conversation we had where he offered me a copy of the textbook for class. It was obvious right there how highly he valued knowledge not just for himself, but for others. He was the kind of person you could have one conversation with and know exactly what they value most. If I could sum up my impression of Ray’s life in a few words they would be, “a sense of wonder.” I would frequently get to class early everyday so I had a chance to tap into the wealth of knowledge and library of stories that was Ray MacDonald. We chatted about the many aspects of his life and he asked plenty of questions about mine. As it turns out, his hometown was adjacent to mine, what a small world this is. He was greatly interested in my scientific endeavors and also my hobbies and interests. One particular time he simply asked “Are you a musician?” which diverged into a deep discussion on the beauty of Baroque music, and the strong, but hidden ties to theoretical physics. I am proud to have called him a colleague and a friend. His passing is a loss for the whole scientific community and he will be greatly missed. He had a sense of wonder that is ever so rare and should be cherished when presented. He taught me a lot more than idle chit chat before class. He taught me the importance of passion in your work and the never ending journey in the pursuit of knowledge. These are conversations I will take with me for the rest of my career, and I am forever grateful to have crossed paths with Ray MacDonald. The simple question we can ask ourselves now when contemplating how to celebrate a great mind is, “How can we retain a passion in our work?””

IceCube and Multimessenger Astrophysics



IceCube and Multimessenger Astrophysics

by Francis Halzen and Albrecht Karle

The highest energy radiation reaching us from the universe is not radiation at all, it is mostly protons and some nuclei referred to as cosmic rays. Since they were first detected over one hundred years ago, cosmic rays—highly energetic particles that continuously rain down on Earth from space—have posed an enduring mystery: What creates and launches these particles across such vast distances? Where do they come from, and how do their cosmic accelerators achieve the huge energies and luminosities observed? The greatest motivation to build IceCube was undoubtedly to use neutrinos to explore the extreme universe and to identify the sources of cosmic rays.

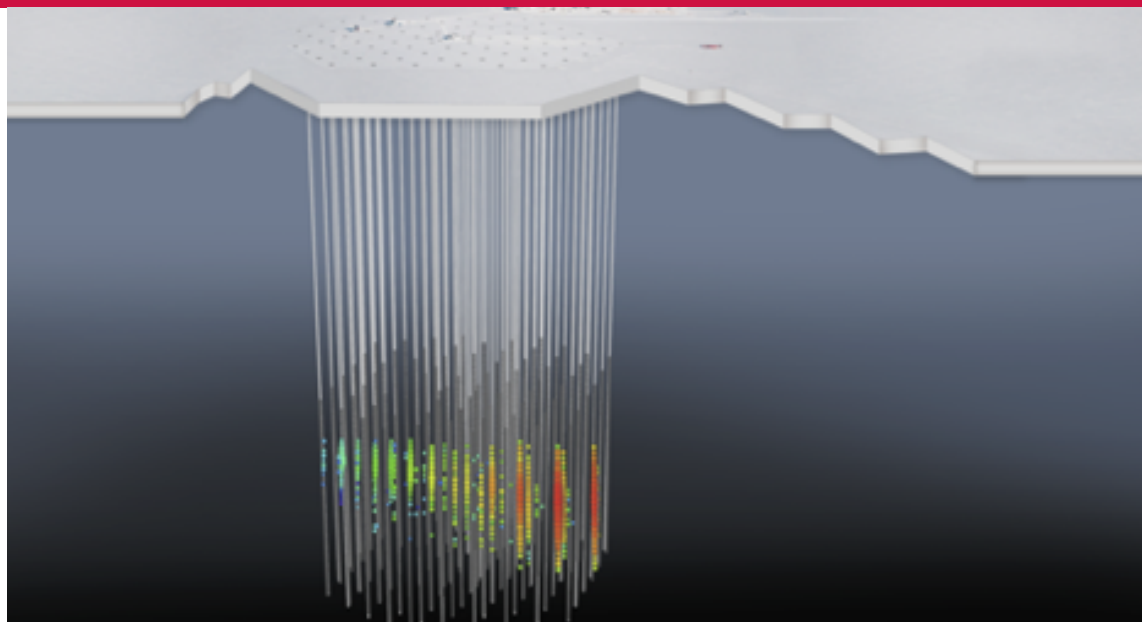
Neutrinos are elementary particles that do not interact with atoms and only weakly interact with nuclei. They can reach us from the edge of space and time and from the inner neighborhoods of black holes. Neutrinos are only produced in environments where protons are accelerated and produce pions and other particles that decay into neutrinos. Neutrinos therefore unambiguously pinpoint cosmic ray accelerators in the sky. One hundred and six years ago, an Austrian physicist named Victor Hess ascended 17,000 feet in a balloon and discovered radiation that was reaching us from the cosmos. The origin of these cosmic particles is one of the oldest problems in astronomy. Cosmic rays fascinate particle physicists because their energy is routinely observed to be more than a million times greater than that of the Large Hadron Collider beams.

We know that, besides cosmic rays, high-energy neutrinos also reach us from the cosmos, as discovered by the IceCube experiment in 2013. IceCube, operated by the Wisconsin IceCube Astroparticle Physics Center (WIPAC) for the NSF at the South Pole, has transformed one cubic kilometer of natural Antarctic ice into a particle physics detector. Since construction was completed at the end of 2010, one of the primary missions of IceCube has been to detect the neutrinos that exclusively pinpoint cosmic ray accelerators, and this is exactly what one neutrino did on September 22, 2017.

IceCube detects muon neutrinos, a type of neutrino that leaves a well-reconstructed track in the detector when it interacts inside or near the detector. We detect such a track every few minutes. Most of them are low-energy neutrinos produced in the Earth's atmosphere, which are interesting for studying neutrinos themselves but are a persistent background when doing neutrino astronomy. In 2016, IceCube installed an online filter that every year selects, in real time, a handful of very high energy neutrinos from this sample that are likely to be of cosmic origin. For these events, we readily reconstruct the properties of the original neutrino from the light pattern in the detector and, within less than one minute, we automatically send out the energy and arrival direction in what we call a neutrino alert to the Gamma-ray Coordinate Network, a group of telescopes around the globe and in space, for follow-up observations. These telescopes look for electromagnetic radiation from the location the neutrino is pointing at, searching for coincident emission that could reveal its origin.

The tenth such alert (GRB Coordinates Network, Circular Service, No. 21916, #1(2017)), IceCube-170922A, on September 22, 2017, reported a well-reconstructed muon neutrino with an energy of 290 TeV and, therefore, with a high probability of originating in an astronomical source.

IceCube and Multimessenger Astrophysics



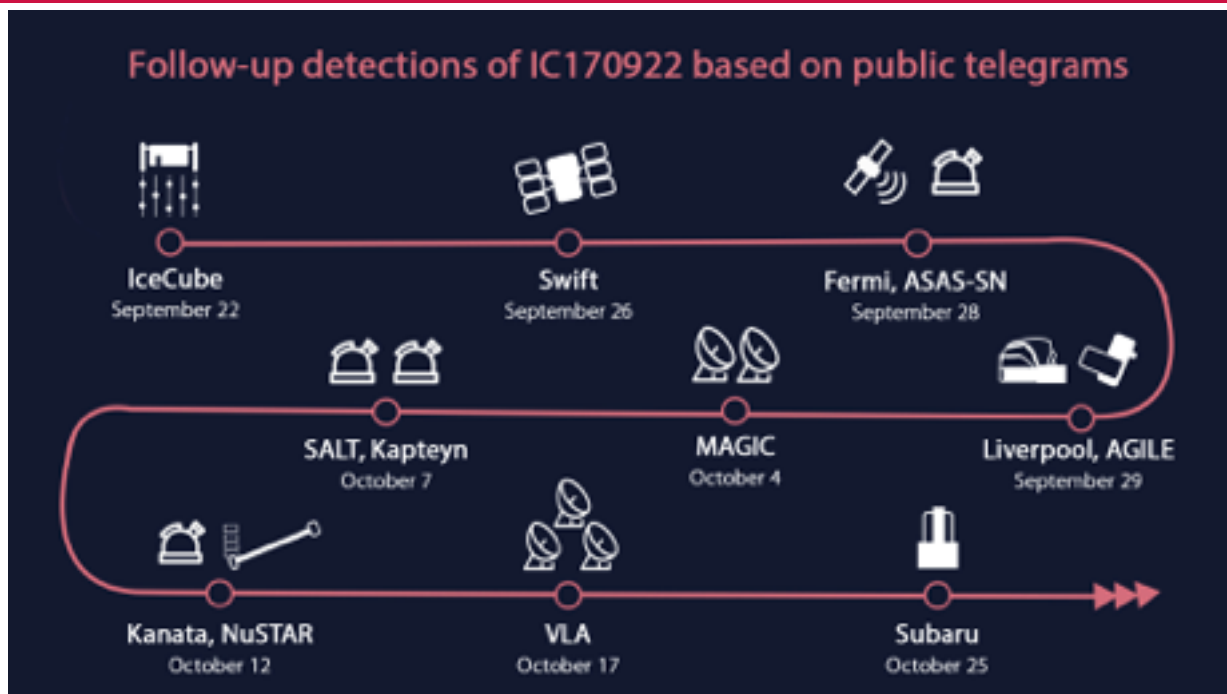
What makes this neutrino special is that, for the first time, telescopes detected enhanced gamma-ray activity from a flaring blazar aligned with the cosmic neutrino to within 0.06° . The source is a known blazar, a supermassive spinning black hole, spitting out high-energy particles in twin jets aligned with its rotation axis and directed at Earth. This blazar, named TXS 0506+056 by astronomers, had been relatively poorly studied until now, although it was associated with the highest energy gamma rays detected by EGRET from any blazar with two gamma rays above 40 GeV. EGRET was Fermi's predecessor. The set of observations triggered by the Sept. 22 neutrino has yielded a treasure trove of data, including the critical fact that it accelerates protons, which will allow us to probe the physics of the first cosmic ray accelerator. An optical telescope eventually measured its distance (S. Paiano et al., *Astrophys. J.* 854 (2018) L32, 1802.01939), which was found to be 4 billion light-years. Its large distance suggests a special galaxy, which sets it apart from the ten-times-closer blazars, such as the Markarian sources that dominate the extreme gamma-ray sky observed by NASA's Fermi satellite.

TXS 0506+056 was originally flagged by the Fermi (Astronomer's Telegram 10791 (2017)) and Swift (Astronomer's Telegram 10792 (2017)) satellite telescopes. Follow-up observations with the MAGIC air Cherenkov telescope (Astronomer's Telegram 10817 (2017)) identified the "Texas" source as a rare TeV gamma-ray blazar with the potential to produce the very high energy neutrinos detected by IceCube. The source was subsequently scrutinized in X-ray, optical, and radio wavelengths. This is a first, truly multimessenger observation: none of the instruments could have made this breakthrough independently. In total, more than 20 telescopes observed the flaring blazar as a highly variable source in a high flaring state (IceCube Collaboration et al., *Science* 361, eaat1378 (2018). 10.1126/science.aat1378).

Once we knew where to look, IceCube searched its archival neutrino data up to and including October 2017. And to our own surprise, we found a spectacular burst of 15 high-energy neutrinos in 110 days. We can speculate how a subset of blazars, around 10% of all blazars, bursting once in 10 years at the levels of TXS, can explain the level of the flux of all neutrinos detected by IceCube to date. But the picture gets even more exciting because the energy of the neutrinos coming from these flaring blazars is at the same level as the energy detected in extragalactic cosmic rays.

As you might guess, getting all the elements of this puzzle to fit together is not easy, but they build a compelling case that the blazar is a source of high-energy cosmic rays and neutrinos.

IceCube and Multimessenger Astrophysics



And our excitement reached a maximum when, upon further analysis, we found that all high-energy spectra, for both photons and neutrinos, including the 2014 and 2017 bursts, are consistent with the energy variation expected for a cosmic accelerator.

It is interesting to note that on July 31, 2016, IceCube had sent out a similar alert. The AGILE collaboration, which operates an orbiting X-ray and gamma-ray telescope, reported a daylong flare in the direction of the neutrino, one day before it was detected. In light of the rapid daily variations observed near the peak emission of the TXS flare at the time of IC170922, this may well be a genuine coincidence.

It is important to realize that the detection of the “Texas” source is the first genuine multimessenger event. Without the initial coincident observation, IC170922A would be just one more of the few hundred cosmic neutrinos detected by IceCube and one more flaring blazar observed by Fermi-LAT. MAGIC may have never looked for anything.

We now know one source of cosmic rays. This breakthrough is just the beginning and raises intriguing questions. What is special about it? Can the subclass of blazars to which it belongs accommodate the diffuse flux observed by IceCube? Are they the sources of all high-energy cosmic rays or only some of them? The TXS06506+056 emission over the last 10 years is dominated by the single flare in 2014. If this is characteristic of the subclass of sources that it belongs to, identifying additional sources will be difficult unless we can build more and larger neutrino telescopes to accelerate progress in neutrino astronomy.

Neutrino astronomy was born with a supernova in 1987. Thirty years later, this recent event involves neutrinos that are tens of millions of times more energetic and are from a source a hundred thousand times more distant.

IceCube recently received funding to prepare for a Phase1 upgrade of 7 highly instrumented strings. This upgrade is seen as a first step for a large upgrade that would increase the instrumented volume of IceCube by a factor of 8. The first drilling season is planned for 2022/23. The IceCube story continues.

New Graduate Degree Option in Physics

MASTER OF SCIENCE IN PHYSICS – QUANTUM COMPUTING (MSP-QC)

*Professor Robert Joynt, Director of the MSP-QC Program
Michelle Holland, Physics Graduate Program Coordinator*

The department has just introduced this new Masters of Science program, designed to prepare students in Quantum Computing. It's an educational innovation that will serve students seeking to study the physics of quantum computing at an advanced level. Governments and private companies around the world are investing heavily in quantum computing as it makes the transition from a field of pure research to a promising technology. Thus, there is a very rapidly growing job market that is currently underserved by universities. We aim to make UW-Madison the premier training ground in the world for this burgeoning field. This MS program is the first of its kind in the United States and we are trying to get ahead of the curve.

The new Quantum Computing program is a 1-year intensive program beginning in the Fall of 2019. The program is intended mainly for students with an undergraduate training in physics, though excellent candidates with degrees in other STEM fields will also be considered for admission. All required courses will be offered by the Physics Department.

Students will receive a thorough grounding in quantum mechanics and more specifically in the application of quantum mechanics to quantum computation. The supporting areas of statistical mechanics, solid-state physics, and atomic physics also form a part of the classroom training. A unique strength of the Physics Department is excellent advanced instructional lab facilities. All students would be required to master the advanced lab skills involved in quantum computation. Graduates of this program will have the tools to succeed as technical staff in modern laboratories that specialize in quantum computing and quantum technologies more generally. They may also use the program as a springboard to Ph.D. programs in Physics and related areas.

The Physics Department currently has a very strong research effort in quantum computing. Profs. Coppersmith, Eriksson, Ioffe, Joynt, Kolkowitz, Levchenko, McDermott, Saffman, Vavilov, Walker, and Yavuz are all active in the field. This area of research is very new; it barely existed before 2000. As such, the current state of training that students receive in most Physics programs is often haphazard and could greatly benefit from the focused comprehensive approach that we plan to take.

The admissions deadline for MSP-QC is March 15th, 2019. We look forward to reviewing applications and accepting the first class for Fall 2019. The target enrollment for the program is 20-25 students per year.

We appreciate any help in spreading the word about our new program. The link to apply is <https://apply.grad.wisc.edu> More information can be found on our website at physics.wisc.edu/mspqc We welcome further questions. Please contact our Graduate Program Coordinator Michelle Holland (michelle.holland@wisc.edu) for general inquiries about the department's graduate programs, and Prof. Robert Joynt (rjoynt@wisc.edu) with inquiries specific to the MSP-QC.

New Graduate Degree Option in Physics



Department of Physics
UNIVERSITY OF WISCONSIN-MADISON



MASTER OF SCIENCE IN PHYSICS QUANTUM COMPUTING

PROGRAM INFORMATION:

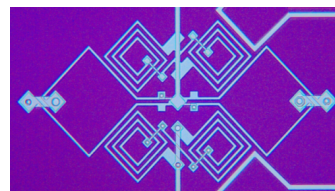
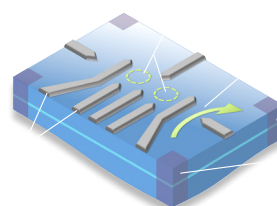
<https://www.physics.wisc.edu/mspgc>

APPLY:

<https://grad.wisc.edu/apply/>

APPLICATION DEADLINE:

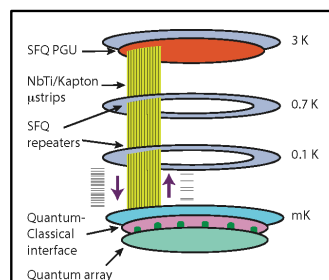
March 15th, 2019



The University of Wisconsin-Madison offers a Master of Science in Physics-Quantum Computing starting in September 2019. This is the only program of its kind in the United States. The intensive one year Master's degree program is designed so that it can be completed in one calendar year.

The program offers a mix of classroom instruction and laboratory experience. Upon graduation you'll be prepared to enter a rapidly growing field with fantastic career opportunities. Be one of the first to take advantage of this unique opportunity!

- International students welcome to apply!
- Experience world class laboratory facilities at the University of Wisconsin-Madison
- One-year degree program
- Explore quantum theory, quantum gates, measurements, algorithms, error correction and decoherence



Contact Professor Robert Joynt, MS-Quantum Computing Program Director (rjoynt@wisc.edu) or Michelle Holland, Graduate Program Coordinator (michelle.Holland@wisc.edu) for more information.

2018 Physics Awards Banquet

The 2018 Physics Physics Banquet & Awards Ceremony to honor the Department Award Recipients and Alumni Fellows was held on Friday, May 4th, 2018 at the The University Club. We honored our award winners with a reception, dinner, and an awards ceremony for their family and friends.

Undergraduate Awards

Fay Ajzenberg-Selove Award



Alexandra Brukhovetsky

This award is presented to undergraduate women majoring in Physics, Astronomy, or Physics/Astronomy to encourage them to continue their careers in science. The late Dr. Ajzenberg-Selove was a distinguished nuclear physicist who received her Ph.D. in Physics at UW in 1952 and spent most of her career as Professor at the University of

Pennsylvania..

Dr. Maritza Irene Stapanian Crabtree Award



Sara Branson

This fund was established by William Crabtree to honor his wife, Dr. Maritza Crabtree, who graduated with a Physics degree in 1971. This annual award benefits undergraduate students in physics based equally on merit and need.

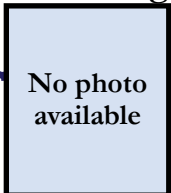
Bernice Durand Undergraduate Research Scholarship



Molly Hetzel

This award was established by Emerita Physics Professor Bernice Durand to promote meaningful undergraduate research and to support and encourage women and ethnic minorities as undergraduate majors in Physics and Astronomy.

Albert Augustus Radtke Scholarship



Eli Mueller

This award stems from a bequest by the late Mrs. Elizabeth Radtke to the University of Wisconsin to recognize outstanding junior and senior undergraduate students majoring in Physics or AMEP.

Henry & Eleanor Firminhac Scholarship Award



Sam Carman

The Fund was established by former UW graduate, the late Ralph Firminhac (BS '41, MS '42). He created this scholarship in memory of his parents, Henry & Eleanor Firminhac.

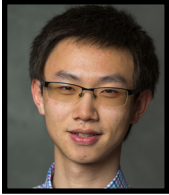
Hagengruber Scholarship



Cory Cotter

This scholarship was established by Roger Hagengruber, for a Wisconsin Resident undergraduate physics student who shows exceptional promise for a future in physics.

Liebenberg Family Research Scholarship



Jerry Zhang

This scholarship is awarded to Physics, AMEP, or Astronomy/Physics majors. This scholarship opportunity was initiated by the Liebenberg family for the purpose of promoting undergraduate summer research opportunities.



2018 Physics Awards Banquet

Graduate Awards

Charles Elwood Mendenhall Award



Leslie Taylor

This award was made possible through the generosity of the Charles Elwood Mendenhall estate. Mendenhall received his Ph.D. from Johns Hopkins in 1898. He was a faculty member in the Department of Physics from 1901 until his passing in 1935.

Allan M. and Arline B. Paul Physics Award



J Joe Olson

The late Mrs. Arline Borer Paul (1914-2012) created this endowment fund, for graduate scholarships in memory of Walter Max Borer. Walter was Arline's brother and received an MS degree in 1937.

Emanuel R. Piore Award



Nathan Holman

The award is made possible through the generosity of the Piore family. It is awarded to the graduate student with the highest score on the qualifier examination.

Elizabeth Hirschfelder Scholarship



Joelle Baer

This Award is to assist women graduate students in Physics at UW - Madison.

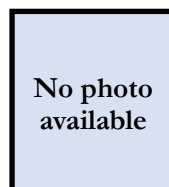
Hallet H. and Mary F. Germond Award



Alex Opremcak

This Award is to provide support for graduate students in the Department. Hallett Hunt Germond, received his Ph.D. in mathematical physics from the University of Wisconsin in 1927.

Cornelius P. and Cynthia C. Browne Award



Ben Lemberger

This Award is established to support graduate students pursuing experimental degrees in honor of Cornelius Browne.

James Nelson Humphrey Award



Harsha Gurram

This Award supports graduate students in physics. James Nelson Humphrey was born in Whitewater, WI, played the French Horn in the UW Marching Band while pursuing his Master's Degree in Physics.

Department TA Awards

Joseph R. Dillinger Award for Teaching Excellence



Joshua Karpel

Best Teaching Assistant



Mitch McNanna (Spring 2017)



Scott Lucchini (Fall 2017)

Rookie of the Year



Alex Pizzuto

Alumni Awards

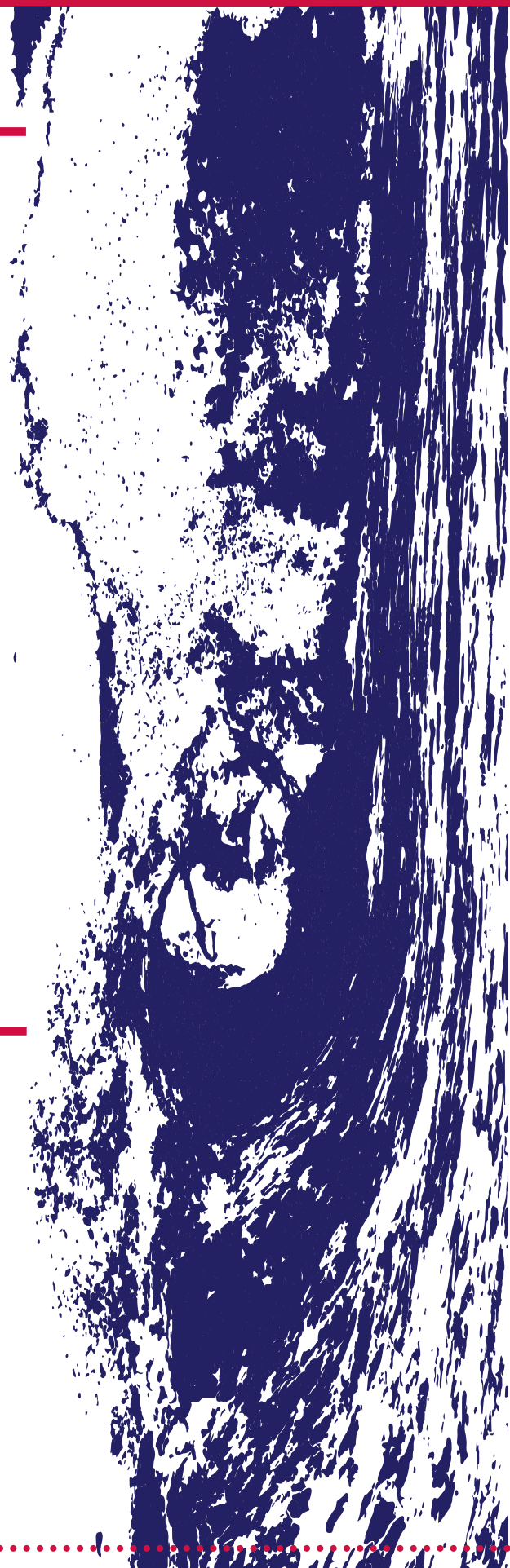
Distinguished Alumni Awards



Janet Seger



Michael Zarnstorff



UW Physics Degrees Awarded

Undergraduate Degrees



Fall 2017

Jambor, Alex
Jarrell, Benjamin
Kelley, Sean
Sutton, Eric
Xiong, Anda

Spring 2018

Adams, Colin
Allen, Christopher
Beheler-Amass, Maggie
Bliss, Thompson
Boukahil, Idris
Buelo, Collin
Carman, Samuel
Cotter, Cory

Dupuis, Nick
Finn, Timothy
Fossum, Scott
Franda, Ryan
Frazier, Matthew
Fronberry, Jacob
Gallogly, Sean
Gruenke, Rachel
Hafeman, Brett
Hickey, Brendan
Keith, Celeste
Kim, Hyunsue
Kowalefski, Jennafer
Lane, John
Lauersdorf, Nicholas
LeFebre, Ryan
Lukasik, Mikey
Malewicz, Sebastian
McConnell, Ryan J
Mueller, Eli
Oster, Charlie

Overstreet, Ryan
Postlewaite, Jack Thomas
Quigley, Daniel
Reeve, Benjamin
Samuelsen, Cole
Schlaman, Brendan
Scott, Michael
Shen, Tianzhe
Stensberg, Jonathan
Tabbutt, Megan
Tomesh, Teague
Tracy, Patrick
Trokan-Tenorio, Jozef
Volety, Sriyotsna
Yang, Bo
Zhang, Ziyuan

Summer 2018

Guckenberger, Aaron

Master Degrees

Fall 2017

Heng, Yang
Mancina, Sarah Louise

Spring 2018

Cheung, Weng-Him
Holdman, Gregory Reid
Newton, Kit
Sayanagi, Richard

Summer 2018

Baker, Bethany
Lichko, Emily
Liu, Chuanhong Vincent
Siller, Robert
Wachtendonk, Megan

Doctoral Degrees

Fall 2017

DeLand, Zachary | Advisor: Walker
Isaacs, Joshua | Advisor: Saffman
Jero, Kyle | Advisor: Karle
Kaplan, Laser Seymour | Advisor: Wu
Rivera, Leonardo | Advisor: Wieben
Woods, Nate | Advisor: Smith

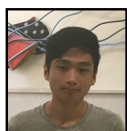
Spring 2018

Brown, Jonathan Hugh | Advisor: Shiu
Dodd, Laura Margaret | Advisor: Smith
Duff, James | Advisor: Sarff
Ju, Xiangyang | Advisor: Wu
Ruggles, Tyler Henry | Advisor: Dasu

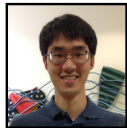
Summer 2018

Beck, Matthew | Advisor: McDermott
Enderich, Daniel | Advisor: McDermott
Faber, Benjamin | Advisor: Hegna
Foote, Ryan | Advisor: Eriksson
Knapp, Trevor J | Advisor: Eriksson
Nishizawa, Takashi | Advisor: Sarff
Pettengill, Duncan William
Suttle, Joseph | Advisor: McDermott

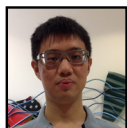
2018 Fall Admissions



Cheng, Chi Lung



Choi, Yujun



Chung, Tzu Tien



Eu, Shu Tian



Fortman, Margaret



Gagrani, Praful



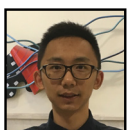
Gardill, Aedan Robert
Hyland



Gonzalez Lozano, Sandra
Jimena



Harpt, Benjamin Elton



Hu, Yue



Huemann, Zach



Huft, Preston



Korwar, Mrunal
Prashant



Losert, Merritt



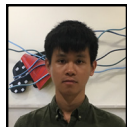
Luu, Bryan Loc



Maier, Alleta R



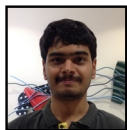
Mode, Brent Alan
William



Pham, Tuan Minh



Podczewinski, John



Riswadkar, Ameya
Shrikrishna



Shearrow, Abigail Joy



Shelton, Emily Mi-
chelle



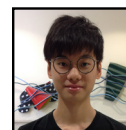
Suen-Lewis, Emma
Marie Jingyi



Tabbutt, Megan Mau-
reen



Tadepalli, Sai Chai-
tanya



Tsoi, Ho Fung



Warden, Abigail
Catherine



Wolfe, Michael Allan

Support Physics via the UW Foundation

Undergraduate



132691618. Fay Ajzenberg-Selove Undergraduate Scholarship provides encouragement for undergraduate women majoring in Physics, Astronomy or Physics-Astronomy to continue their careers in science.

132693412. Dr. Maritza Irene Stapanian Crabtree Undergraduate Scholarship provides assistance to undergraduate students based on merit and need.

132693561. Bernice Durand Research Scholarship promotes meaningful undergraduate research opportunities, plus supports and encourages women and ethnic minorities as undergraduate majors in the Departments of Physics and Astronomy.

132693645. Henry & Eleanor Firminhac Scholarship provides assistance to students in Physics with financial need. (Undergraduate or Graduate)

132692683. Liebenberg Family Research Scholarship supports Physics, AMEP or Astronomy-Physics majors in summer research experiences.

132697989. Hagenruber Fund provides assistance to undergraduate physics students who are Wisconsin residents with financial need; and who show exceptional promise for a future in physics or a related field.

112697824. Physics Board of Visitors Undergraduate Research Fund provides funding for awards that will assist directed study projects in pure and applied physics; multidisciplinary projects linking physics to such fields as biology; engineering; business; and creative expression; and participation in related conferences.

Graduate

132697960. Allan M. and Arline B. Paul Physics Fund provides support to graduate students in memory of Walter Max Borer (MS 1937).

132697988. Carl and Brynn Anderson Graduate Physics Fund provides support for graduate student recruitment and retention, travel for study and research, materials for study or research; recognizing achievement in scholarship.

132697201. Casey M. Durand Graduate Fund provides support, in memory of Albert R. Erwin, Jr., to graduate students working in experimental high energy physics.

132692082. Cornelius P. & Cynthia C. Browne Endowed Fellowship Fund provides support to graduate students pursuing doctoral studies in the Physics Department.

132693190. Elizabeth S. Hirschfelder Endowment supports women graduate students in Physics research.

132691960. Jeff & Lily Chen Wisconsin Distinguished Graduate Fellowship provides a full year fellowship to an outstanding graduate student in the department.

132691359. Joseph R. Dillinger Teaching Award Fund provides recognition to an outstanding teaching assistant in the Department of Physics.

132693916. Karl & Alice Knapp Jansky Fellowship Fund provides alternate year funding to an outstanding graduate student in Physics and Astronomy.

132696175. Phyllis Jane Fleming Graduate Student Support Fund provides support for a female doctoral candidate in any year of training in physics.

112698294. Physics Alumni Graduate Award Fund provides support to incoming graduate students who hold Teaching Assistant appointments in the department.

132695150. E. R. Piore Award provides support to the recipients of the highest qualifying exam scores each semester.

132692106. Graduate Student Recruiting provides assistance in recruitment expenses of Physics graduate students.

132691808 and 132692368. Ray & Anne Herb Wisconsin Distinguished Graduate Fellowships provides a full year fellowship to one or two outstanding graduate students engaged in materials research in the department.

132697430. Robertson Leach Graduate Student Fund provides support for incoming, first year graduate students in the department.

112696443. L. Wilmer Anderson & Dave Huber Graduate Support Fund provides a number of awards to new graduate students entering the department. This award is in honor of Profs. L. Wilmer Anderson and David Huber.

132695370. Van Vleck Fellowship Fund in Physics provides support to graduate students in the department.

Research

132694421. Barschall Enterprise Fund was established in 2005 in honor of former Professor Heinz Barschall. Provides unrestricted-use fund for Chair in recruiting senior researchers to faculty.

132906418. David Grainger Physics Library Fund provides funding for the acquisition of books and other materials related to physics.

132694069. Friends of the Physics L. R. Ingersoll Museum provides funding for museum display upgrades and student docents.

112694622. Physics Community-Building Fund provides funding for Chair in establishing and reaffirming a sense of community among the faculty, staff, students, and alumni of the Department.

112698078. Wonders of Physics Outreach Fund provides support for the continuation of the Wonders of Physics annual shows as well as the grade school show program.

132692106. Atomic Collision Research Fund encourages

and supports research on atomic collision processes and their application to studies of weakly ionized gases in perpetuity.

112691418. Elementary Particle Physics Institute provides funding for activities of the institute.

132690387. L. R. Ingersoll Fund provides support for colloquia and seminars in the department.

132691720. Physics Newton Fund is a general, unrestricted fund administered by the Department Chair. The purpose of this fund is to aid the Department of Physics in its research, teaching and public service roles.

132697999. Quantum Computing Research Center Fund provides support for research in quantum computing in the physics department.

112696250. Thomas G. Rosenmeyer Cosmology Fund provides support for the Prof. Peter Timbie research group in its teaching, research, and public service roles.

Support Physics

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Milwaukee, WI 53278-0807

My gift of \$ _____, payable to the University of Wisconsin Foundation, is enclosed.

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Cardholder Signature: _____ Date: _____

Name: _____ Home Phone: (_____) _____

Address: _____

City, State, ZIP: _____

For a description of all UW Foundation Physics Funds, go to: <http://www.physics.wisc.edu/donate/funds>

My Gift

I wish to designate my Gift to the following fund(s)

- Physics Newton Fund (#1269172)**—An unrestricted general fund—greatest need.
- Undergraduate Support—General (#1269172)**
To provide for undergraduate student special needs.
- Undergraduate Support—Specific**
Indicate fund name and number below.
Select from list of “undergraduate” funds on previous page.
Fund Name: _____ Fund Number: _____
- Graduate Support—General (#1269172)**
To provide for graduate student special needs.
- Graduate Support—Specific**
Indicate fund name and number below.
Select from list of “graduate” funds on previous page.
Fund Name: _____ Fund Number: _____
- Research**
Indicate fund name and number below. Select from list of “Research” funds on previous page.
Fund Name: _____ Fund Number: _____

Should you prefer to make your donation electronically by credit card on a secure server, please go to: <http://www.physics.wisc.edu/donate/funds>. Click on the fund in which you are interested for information and then complete the UW Foundation secure site form.

If you wish to consult with a UW Foundation Development officer on your gift or other options including estates, trusts, gifts in kind, or planned giving, please call the University of Wisconsin Foundation at 608-265-9952.



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