Physics INTERACTIONS

A NEWSLETTER HIGHLIGHTING THE DEPARTMENT OF PHYSICS AND ASTRONOMY AT PURDUE UNIVERSITY

2015

Physics and Astronomy on the Road provides opportunities for students to experience science in unusual ways

Undergraduate service learning student Trey Roob demonstrating the forces of his vortex cannon with 5th and 6th graders.

Inside

From the Head

Fall, despite the ramifications of the season, is always a time for new things in academia; new classes, new students, new challenges. This fall semester is a particularly eventful one for me as I begin my tenure as the new Department Head in Physics and Astronomy. I assumed the position in the beginning of August and took over from Andy Hirsch who capably kept the department on track for 2 years as the Interim Head. I was honored and humbled to be chosen to lead such an esteemed group of academics that I call colleagues as well as friends. I have been spending the past few months learning new things (hmmm, just like everyone else) and getting acclimated to my new duties. I will pledge myself to you, the alumni and friends of the department, to keep Purdue Physics and Astronomy moving forward into the 21st century.

Things are always in a state of flux in the department. We welcomed 4 new faculty this year. Assistant Prof. Rudrow Biswas is a condensed matter theorist whose last appointment was at Argonne National Laboratory. Assistant Prof. Srividya Iyer-Biswas is an experimental biophysicist that has made the trip south from the University of Chicago. Assistant Prof. Andreas Jung is an experimental high energy physicist who was most recently involved in the CMS collaboration at Fermilab. Finally, Prof. Sanjay Rebello made the move east from Kansas State University to join our burgeoning physics education research group. All, like myself, are settling in and learning the new playing field.

Our faculty continue to garner honors and awards from their professional societies and peers. We were so proud to be informed that 2 of our faculty were honored as Fellows of the American Physical Society; Prof. Erica Carlson and Prof. Michael Manfra. APS bestows this honor on only 0.5% of its members. Well done, Erica and Mike! Prof. Andrew Mugler was awarded a Simons Investigator grant in the area of Mathematical Modeling of Living Systems, joining a small group of investigators from across the country to receive this recognition. Congratulations to Andrew! The department has also been recognized by the American Institute of Physics as one of the departments that conferred the largest number of undergraduate physics degrees.

These laudable accomplishments would not be possible without the support of you, our devoted alumni. Purdue just kicked off a new capital campaign titled “Ever Grateful Ever True” (I’m sure you’ll hear about it!) with the goal of raising over $2 Billion for student and faculty support amongst other goals. I am always impressed to hear that despite having an alumni base much smaller than other departments (we have fewer majors after all) you have a much higher degree of affinity. You are proud to be alumni of this department and we are proud to have you as alums! Your role as an important part of our mission didn’t end when your degree was conferred and we deeply appreciate your continued support. I will commit myself to doing your support justice and to continue making you proud Boilermakers.

John Finley

Credits

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Department Head
John P. Finley

Editor
William L. Fornes
wfornes@purdue.edu
765-494-3001

Contact Information
Department of Physics and Astronomy
525 Northwestern Avenue
West Lafayette, IN
47907-2036

www.physics.purdue.edu
Telephone: 765-494-3000
Fax: 765-494-0706

An electronic version is available at:
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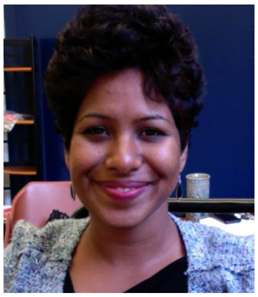
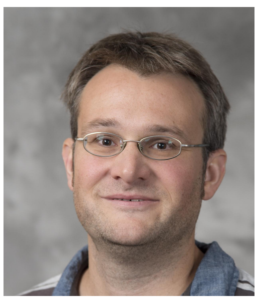
Front Cover Credit:

New Faculty

Rudro Biswas, Assistant Professor of Physics and Astronomy is a theoretical condensed matter physicist whose research focuses on geometrical aspects of quantum states of matter and impurities, defects, and disorders in exotic materials. Prof. Biswas received his B.S. from Presidency College, Calcutta University and a M.A. and Ph.D from Harvard University. He was previously a postdoc at the University of Illinois at Urbana-Champaign and at Argonne National Laboratory.



Srividya Iyer-Biswas, Assistant Professor of Physics and Astronomy, specializes in experimental biophysics. Her specific research interests are in the principles of cellular timekeeping, signatures of transient dynamics in single cells, and paradigms of sustained biological symmetry breaking. Prof. Iyer-Biswas comes to Purdue from the University of Chicago where she has a postdoctoral research associate with the James Franck Institute. She holds a B.S. from St. Xavier's College, Calcutta University, a M.S. from the Indian Institute of Technology, and a Ph.D. from The Ohio State University.



Andreas Jung, Assistant Professor of Physics and Astronomy, specializes in experimental high energy physics. His research interests are measurement of top quark Yukawa coupling, direct and indirect top quark partner searches, precision cross-section measurements, and dark matter. Prof. Jung comes to Purdue from Fermi National Accelerator Laboratory where he has a research associate with the CMS and D0 experiments. He holds a diploma in physics from the University of Dortmund and a doctorate in physics from the University of Heidelberg.

Sanjay Rebello, Professor of Physics and Astronomy, is a physics education researcher interested in the transfer of learning its implications for STEM teacher education. In particular, he investigates the development of instructional experiences for the preparation of future teachers that are consistent with Next Generation Science Standards. Prof. Rebello comes to Purdue from Kansas State University where he was the Ernest K and Lillian E Chapin Professor of Physics. After earning a B.E. (Electrical and Electronics Engineering and M.S. (Physics) at Birla Institute of Technology and Science, he received a dual M.S. (Physics and Electrical Engineering) and a Ph.D. (Physics) from Brown University.

Retired Faculty

Prof. Rolf Scharenberg
Years of Service: 1965-2014

Did You Know?

The Department of Physics and Astronomy currently has 61 faculty members.

Faculty Honors

Erica Carlson was named a Fellow of the American Physical Society.

Maxim Lyutikov was promoted to Professor.

Steven Durbin received the College of Science Team Award.

Michael Manfra was named a Fellow of the American Physical Society.

Martin Kruczenski was promoted to Professor.

Andrew Mugler received a 2015 Showalter Trust Award and was named a Simons Foundation Investigator.

Rafael Lang received the Ruth and Joel Spira Award for Outstanding Undergraduate Teaching.

Yulia Pushkar received the Physics Graduate Student Association Outstanding Advisor Award.

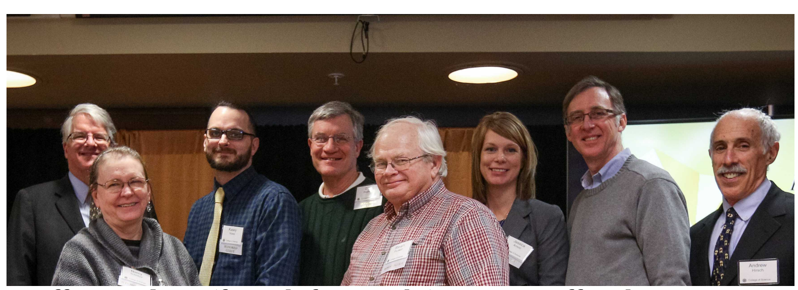
Sherwin Love received the Ruth and Joel Spira Award for Outstanding Graduate Teaching.

Sergei Savikhin was promoted to Professor.

Staff Recognitions

College of Science Customer Service Award
Jessica Arnold
Kasey Howe
Gary Hudson
Steve Plunkett
Nancy Schnepp

Eleanor Kaplan Award for Exceptional Customer Service
Jessica Arnold



Staff Awardees (from left to right): Dean Jeff Roberts, Nancy Schnepp, Kasey Howe, Gary Hudson, Steve Plunkett, Jessica Arnold, Steven Durbin, and Department Head Andy Hirsch.

Graduate Student Awards

AAPT Outstanding Teaching Assistant
Michael Meier
Cyrus Vandrevala

Akeley-Mandler Award for Teaching Excellence
David Blasing

Bilsland Dissertation Fellowship
Ting-Fung Chung
Ethan Kleinbaum
Deke Sun
James Tucci

Edward S. Akeley Award
Su-Ju Wang

Gabriele F. Giuliani Award
Darryl Masson
Julian Varennes

George W. Tautfest Award
Kurt Jung

H.Y. Fan Award
Yang Xu

Karl Lark-Horovitz Award
Ethan Kleinbaum

Lijuan Wang Award
Mayra Cervantes
Su-Ju Wang

Teaching Academy Graduate Teaching Award
Ian Arnold
Zachary Mitchell

Undergraduate Student Awards

AAPT Outstanding Learning Assistant
Benjamin Fasig

Arthur N. Pozner Scholarship
Nicholas Cinko
Cameron McLenaghan

College of Science Outstanding Student Award
Jarian Bailey (Fr)
Nicholas Cinko (So)
Hui Yu (Jr)
Bennett Marsh (Sr)

David G. Seiler Physics Scholarship
Alaina Glidden
Lauren Kolkman

Judith Peters Humnicky Memorial Award
Lauren Hucek

Kenneth S. and Paula D. Krane Scholarship
Gavin Cox
Zachary Schroeder
Daniel Sweeney

Lijuan Wang Award
Jenna Burnett
Alison Hoe
Rachel Maxwell
Anna Harris
Jennifer Larson

Margie and Don Bottorff Physics Scholarship
Jarian Bailey
Alex Konic
Elizabeth Spiers
Samuel Higginbotham
Brian May
Franklin Talbert
Yang Mo

Outstanding Future Educator
Kyle Isch

Richard W. King Award
Samuel Higginbotham (Jr)
Bennett Marsh (Sr)

Shalim and Paul Sargis Memorial Scholarship
Scott Behmer
Alison Hoe
Joshua Leeman

Spira Summer Research Award
Daniel Sweeney
Elisha Rothenbush

Graduate Research Focus

Probing the Dark Side

Mayra Cervantes

Dark matter is an abundant, yet unseen type of matter in the universe. Its gravitational effects have been observed from scale of galaxy clusters down to individual galaxies. We know that Dark Matter does not interact electromagnetically since does not emit any light. However it may interact with ordinary matter through other forces. In order to probe the hypothesis that Dark Matter, might interact with the weak force scientists are attempting to detect dark matter through a variety of experiments. XENON is one of these experiments.

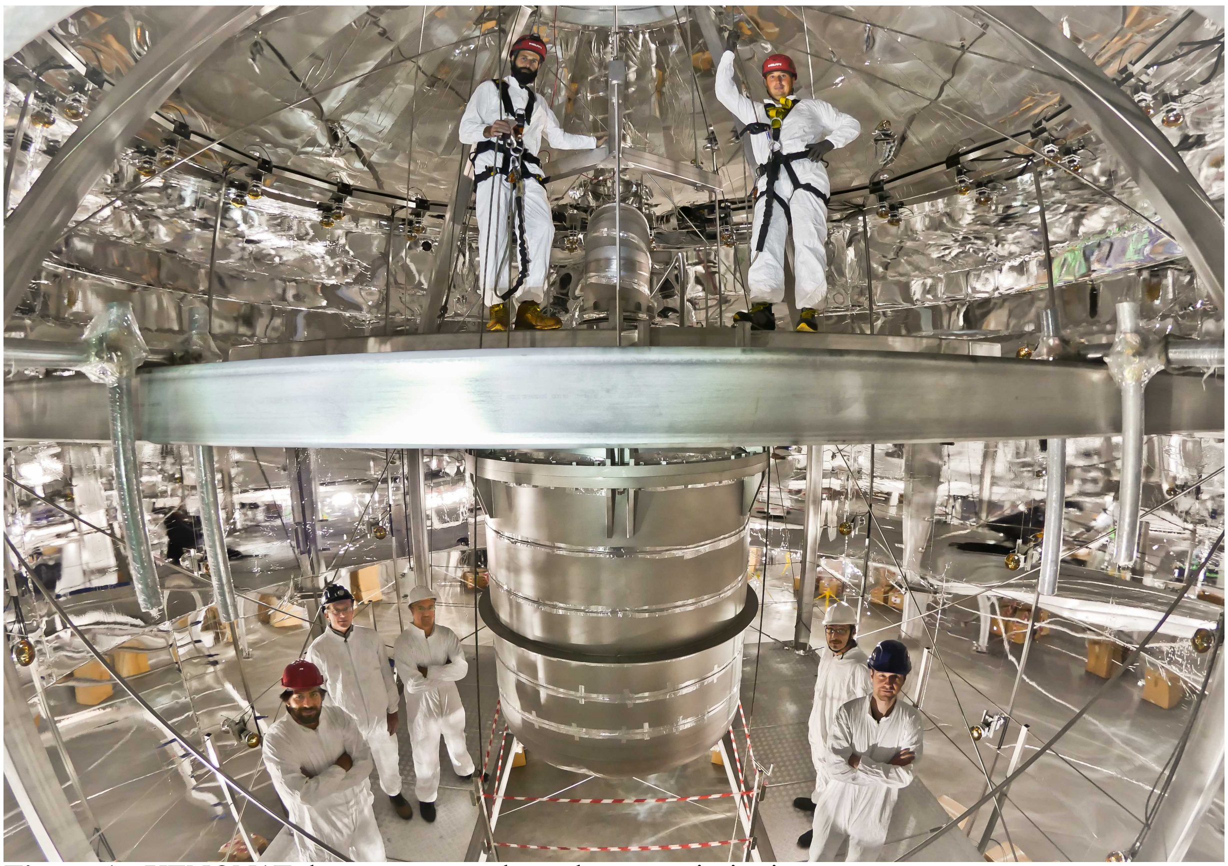


Figure 1: XENON1T detector currently under commissioning. *(Courtesy of XENON Collaboration)*

The idea is simple, Dark Matter particles, that traverse the galaxy at velocities of 250 km/s and pass through detectors here on Earth, may interact with the target of a detector. The goal of the direct detection experiments is to measure the tiny amount of energy transferred to the nuclei by the Dark Matter. Two things make these types of experiments very challenging. The probability of interaction between the Dark Matter and the nuclei is very small. In order to increase our chances of seeing this rare interaction, we must build massive detectors to increase the chance of an interaction. Second, because the deposited energy is tiny, detectors need to be extremely sensitive.

Dark Matter experiments have to be located deep underground in order to suppress cosmic rays. The XENON experiment is located at the Gran Sasso Underground Laboratory in Italy at an average depth of 3600m water equivalent where only one of a million cosmic rays are left over . We use liquid xenon as the detecting material, hence the name.

As of today XENON, as well as other similar experiments, has reported null results. That is, no evidence has been found of Dark Matter interacting with a target's nuclei. But what about electrons? Can Dark Matter interact with electrons? If Dark Matter behaves like we expect, then no, most likely it wouldn't. Well motivated dark matter models, such as supersymmetry, predict that Dark Matter will interact mostly with the target nuclei of the detector. However, in recent years, we have begun to appreciate more and more the fact that Dark Matter could behave very differently in many ways. Experimental anomalies like the controversial annual modulation signal observed in the DAMA/LIBRA project cannot be explained by traditional dark matter scattering on atomic nuclei. However they could be accommodated if Dark Matter scatters predominantly off electrons or if most of the scattering energy is released in the form of photons.

For a long time, it was considered unfeasible to test such a leptophilic model (Dark Matter interacting with electrons) since these interactions are much more difficult to distinguish from radioactive backgrounds that are inherently present in any detector. Thanks to careful design and selection of materials, the XENON experiment is setting the new gold standard in low background Dark Matter experiments.

Figure 2 shows the electronic recoil rate observed in XENON100 (blue) and the modulated and total rate of DAMA/LIBRA (red and pink). The total rate in the XENON detector is more than two orders of magnitude lower than the average background rate reported by DAMA/LIBRA, and it is even smaller than their reported annual modulation amplitude. This essentially rules out any Dark Matter interpretation of the DAMA/LIBRA signal.

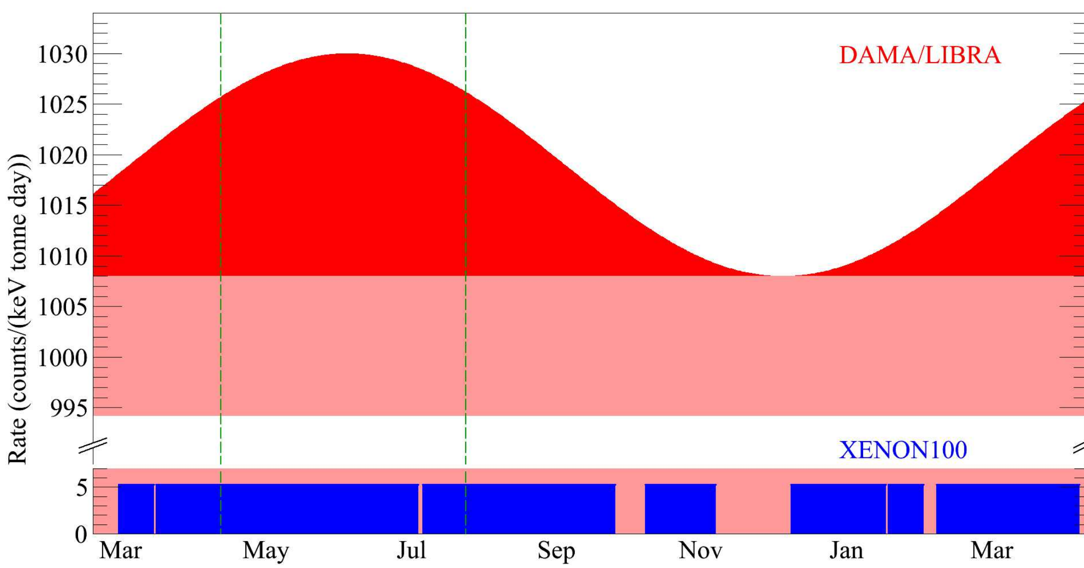


Figure 2: Concept illustration of the analysis

In an article recently published in the Science magazine [1] we carefully contrast the DAMA/LIBRA signal according to three representative leptophilic models. In all cases we found our data to be incompatible with any of these interpretations of DAMA signal.

To go forward on the hunt for Dark Matter we are now commissioning the new larger and more sensitive detector with a total of 3200 kg of liquid xenon. It has a sensitivity that is two orders of magnitude beyond our current knowledge. Over the next couple of years XENON1T will probe our most promising Dark Matter models and will be able to conclusively determine whether or not Dark Matter exists in the ranges we expect.

[1] Exclusion of leptophilic Dark Matter Models using XENON100 electronic recoil data, E.Aprile et. al Science 349, 851 (2015)

Ms. Cervantes is advised by Prof. Rafael Lang. XENON1T is supported by the National Science Foundation, Department of Energy, Swiss National Science Foundation, Volkswagen Foundation, Bundesministerium für Bildung und Forschung, Max Planck Gesellschaft, Research Center Elementary Forces and Mathematical Foundations, Foundation for Fundamental Research on Matter, Weizmann Institute of Science, Initial Training Network Invisibles, Fundacao para a Ciencia e a Tecnologia, Region des Pays de la Loire, Science and Technology Commission of Shanghai Municipality, National Natural Science Foundation of China, and Istituto Nazionale di Fisica Nucleare.

Purdue Rare Isotope MEasurement (PRIME) Lab

Marc Caffee

The bounty of scarcity. These two descriptors are usually thought of as opposites, but in some instances one leads to the other. This is the case for a group of radionuclides found in solar system materials (Table 1). The scarcity of these radionuclides has led to a bounty of geologic, environmental, and biomedical applications. This group of nuclides are characterized by half-lives that are short relative to the age of Earth and the solar system but long by human standards. Precise mass spectrometric measurements of decay products of these radionuclides shown in Table 1 indicate that they were present in the early solar system, indeed ^{26}Al, which decays to ^{26}Mg, is believed to be the heat source responsible for differentiation of meteorite parent bodies. But the age of the solar system, based on Pb isotopes (among others), is 4.568 Gyr; Earth's age is 4.54 Gyr. These radionuclides were present in the early solar system, but hundreds to thousands have half-lives of these nuclides have elapsed; the original inventory of these nuclides incorporated into Earth is for all practical purposes extinct.

Table 1. Long-lived radionuclides measured by AMS

Nuclide	Half-life (years)
^{10}Be	1.36×10^6
^{14}C	5730
^{26}Al	7.17×10^5
^{36}Cl	3.01×10^5
^{41}Ca	1.02×10^5
^{129}I	1.57×10^7

There are a few processes though that produce trace quantities of these radionuclides. The production rates of these processes are low, so although they are not extinct they are scarce. The two processes that account for their production are cosmic ray interactions and nuclear decay processes. Be-10 is an illustrative example - it is made by cosmic-ray interactions. Galactic cosmic rays bombarding Earth's atmosphere produce a secondary cascade of neutrons. These neutrons permeate the atmosphere and reach Earth's crust, penetrating several meters before stopping. Neutrons colliding with O and N in the atmosphere produce ^{10}Be (Figure 1), commonly referred to as meteoric ^{10}Be. Likewise, the collisions between neutrons and commonly-occurring rock-forming elements yield *in-situ* ^{10}Be. Iodine-129, on the other hand is produced dominantly by uranium decay, although cosmic-ray interactions with tellurium produce ^{129}I as well. Chlorine-36 can be produced by cosmic-ray processes, and also by nucleogenic processes; neutrons from decay processes can be captured by ^{35}Cl, producing ^{36}Cl.

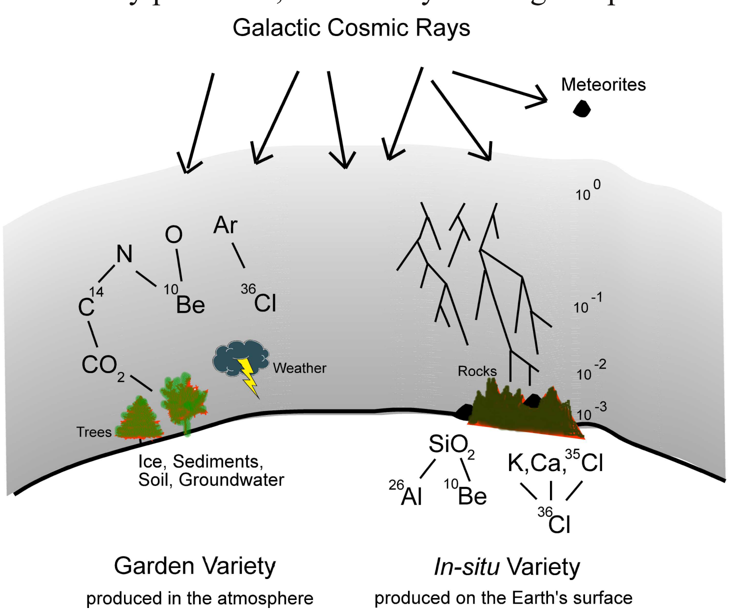


Figure 1: Production of cosmic-ray-produced nuclides

It is the definitive realization that only a limited number of processes can produce these nuclides that leads to the bounty and richness of applications. When we measure ^{10}Be and ^{26}Al in samples, for example, we know those nuclides were produced by the secondary neutron cascade from galactic cosmic rays. To be useful though, we must know the production rates for these nuclides. We know from independently dated calibration sites that the *in-situ* ^{10}Be production rate in quartz is ~ 4 atoms/gm-yr at sea-level and high latitude (> 60°). We have experimentally validated scaling models that allow us to calculate the production rate at different geographic locations. The ^{26}Al production rate is 6.75 times the ^{10}Be production rate; the ^{26}Al/^{10}Be production rate ratio does not vary much as a function of geographic location. These production rates bring us back to scarcity. The won't be many atoms of these specific nuclides present in many samples, and even if there are, how can they be measured? The problem with Al is particularly acute since Earth's crust is awash is ^{27}Al, so even if some ^{26}Al is made, will it be detectable against a ubiquitous ^{27}Al background? In quartz, which through geochemical processes largely excludes Al from its mineral lattice, the $^{26}Al/^{27}Al$ will range from 1 x 10^{-13} to < 1 x 10^{-15}. The ability of a mass spectrometry to detect an isotope (such as ^{26}Al) 1 amu away from another more abundant isotope (such as ^{27}Al) is referred to as the abundance sensitivity. Most mass spectrometers have an abundance sensitivity in the ppm range, some even as low as 10^{-8}, still 5-7 orders of magnitude shy of that needed to measure ^{26}Al, ^{10}Be, or other radionuclides produced by cosmic rays.

Isotope pairs having abundance sensitivities in this range can however be measured using accelerator mass spectrometry (AMS). The PRIME Lab at Purdue University, housed in the Department of Physics and Astronomy, specializes in measuring ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{129}I. Using a tandem Van de Graaff to accelerate the injected ions to 10s of MeV enables multiple stages of high-mass-resolution mass analysis in conjunction with isobar suppression techniques (Figure 2).

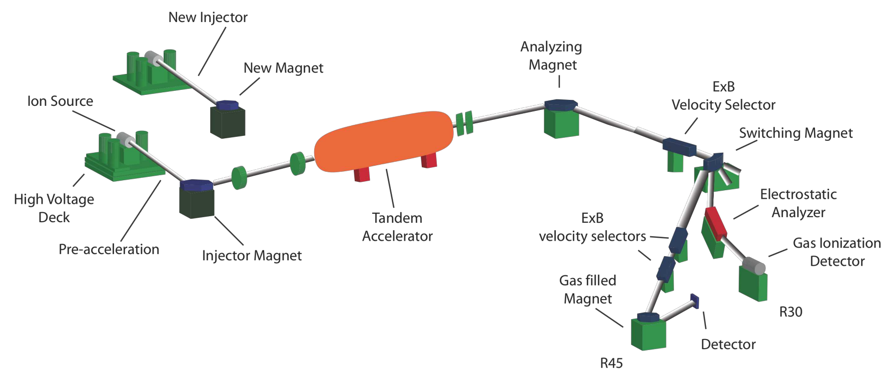


Figure 2: PRIME Lab AMS facility

Cosmic-ray-produced radionuclides produced *in-situ* in terrestrial rocks are now routinely used to characterize multiple processes, including determination of glacial retreat chronologies, erosion rates, slip-rates from tectonic processes, and burial ages. In most instances the rates, chronologies, or ages simply cannot be obtained by other techniques making AMS measurements an essential component of landform evolution studies.

Figure 3: Little Foot *(Courtesy of the University of the Witwatersrand)*

Burial ages represent one of the most exciting applications of in-situ cosmic-ray-produced nuclides. Quartz grains residing on the surface are exposed to the secondary neutron cascade, so ^{10}Be and ^{26}Al accumulate in an amount proportional to the exposure time. If these quartz grains are then buried, that is shielded from further exposure to neutrons, then the ^{10}Be and ^{26}Al begin decaying at a rate given by their half-lives (Table 1). Since the ^{26}Al half-life is about a factor of two less than ^{10}Be, it decays quicker so a buried sample will have a $^{26}Al/^{10}Be$ smaller than the production rate ratio of 6.75. The amount by which it is less is proportional to the burial age.

Caves collect sediments, some of which are quartz rich. The $^{26}Al/^{10}Be$ of these quartz grains is then an indicator of when those grains were buried. The burial age of the quartz grains may be of geologic interest but sometimes these caves contain vestiges of other significant events. Sterkfontein, a set of limestone caves northwest of Johannesburg, South Africa. These caves contain numerous hominid remains, including significant finds of *Homo* and *Australopithecus*. It is one of the *Australopithecus* skeletons, an *Australopithecus promotheus* know as Little Foot (Figure 3), that has recently received considerable news coverage. Researchers at Purdue University, in conjunction with other researchers (Granger et al., 2015) have dated these remains using burial dating. The skeleton itself cannot be dated, but they skeleton is encased in a cemented breccia of quartz grains, and these quartz grains were exposed for a long

(continued on page 15)

Physics and Astronomy Outreach at Purdue

David Sederberg

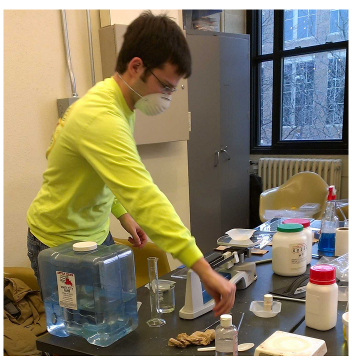
Outreach programs in 2015 in Physics and Astronomy continued time-honored traditions in addition to seeking new ways to engage K-12 learners. Our long-standing Physics on the Road programs, built around unifying conceptual themes, are designed to augment the classroom curriculum in large group settings, providing students novel and engaging opportunities for learning. In our Liquid Nitrogen Show Starring N_2, students observe and actually feel, hear, and experience first hand the effects of extreme temperatures on the mechanical, electrical and acoustic properties of materials. Undergraduate and graduate service learning students and volunteers play significant roles in presentations.

Graduate student Andy Hesselbrock directs the behavior of student atoms at extreme temperatures at the Sycamore School Girls STEM conference.

A new star in the Physics and Astronomy Outreach line-up is Saturday Morning Astrophysics (SMAP). Piloted in the 2015 spring semester, we're now in full swing with a two-semester sequence. Once a month SMAP engages grade 6-12 students on campus in hands on activities related to the Big Ideas of astrophysics and astronomy. Matthew Wiesner, a post doctoral researcher in astrophysics organizes the curriculum and serves as SMAP lead instructor, assisted by other post docs, as well graduate and undergraduate volunteers. In the kick-off session for the fall semester, students assembled refractor telescopes, which they were able to take home.

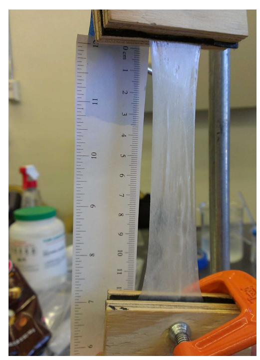
Another new program this year is what we've dubbed Purdue Club. The result of collaboration with high school teachers to fit needs and interests, Purdue Club is an afterschool program aimed at providing opportunities for students to explore STEM disciplines and careers. The monthly programs, presented by Outreach Coordinator David Sederberg and undergraduate students in his Service Learning in Outreach course have included hands-on activities in topics such as Newton's Laws, nanoscale materials, and rocketry. In the most recent session, students synthesized a ferrofluid.

Success stories in outreach most often come from different aspects of our program working to support one another. One of those components vital to our programs is service learning. Service learning is a philosophy by which students make meaningful contributions to the benefit of others while at the same time developing their own knowledge and expertise in an area of personal interest or study. Students mentored in outreach service learning courses have created instructional materials for K-12 classrooms, designed and piloted laboratory experiments, and almost always participate in program presentations. Physics and Astronomy Outreach could not function without this added energy and expertise. As an example, physics major Frankie Bouscher developed a procedure for fabricating and testing the tensile strength of a polymer composite material incorporating a nanoscale component. The lab Frankie developed has been used with our teacher professional development programs and we now provide the materials for teachers who would like to have their own students study uses of nanoscale materials and tensile properties.



Frankie preparing the composite sample.

Pouring and drawing out the film to cure.



Taking data comparing force and stretch.

Teachers perform the experiment in a summer workshop.

Physics and Astronomy Outreach is largely supported through our alumni and friends. For more information the kinds of programs we offer, or to ask what we can do for you, please check us out on the web at http://www.physics.purdue.edu/outreach.

Did You Know?

Research in the department generated over 12 million dollars in 2014-15.

2015 Distinguished Alumni Award

BS 1948 Berea College

MS 1951 Purdue University

PhD 1958 Ohio State University

The Department of Physics and Astronomy and the College of Science honored Warren E. (Gene) Bulman as its 2015 Distinguished Alumnus on April 17, 2015.

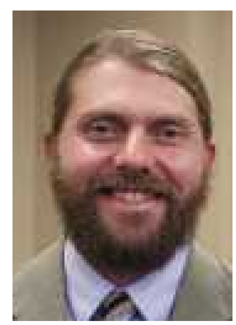
Warren E. (Gene) Bulman (MS 1951)

Dr. Gene Bulman, MS 1951, has distinguished himself as a leader in the semiconductor community. From 1951 to 1952, he was an Electronic Scientist and Physicist with the National Bureau of Standards. From 1952 to 1955, Bulman was at Battelle Memorial Institute where he was Principal Physicist and Group Leader in the solid state devices division. From 1955 to 1958, Dr. Bulman was Associate Supervisor of the Antenna Laboratory at The Ohio State University. In 1956, he organized Ohio Semiconductors, Inc., and was President and Chairman of the Board until 1960 when the company became a division of Tecumseh Products. From 1960 to 1964, Bulman was a Vice President of Tecumseh Products and General Manager of the Ohio Semiconductors Division. In 1964, Dr. Bulman cofounded Ohio Semitronics, Inc. where he served as Chairman of the Board, President and technical leader.

Dr. Bulman is a member of many technical and professional societies including IEEE, American Physical Society and the Electrochemical Society. He is listed in American Men of Science, Who's Who in Industry and Finance in the World and Who's Who in the Midwest. Dr. Bulman's community activities have included Chairman of Blue Cross of Central Ohio, Board of Mercy Hospital, Board of St. Anthony Hospital, Board of Marburn Academy, Board of the United Methodist Children's Home and Whitehall Planning Commission. Bulman is a veteran of World War II. He was a pilot and instructor in the US Army Air Force and served in the China-Burma-India theatre.

2015 Outstanding Alumni Awards

Dr. Andrew Elmore



Dr. Andrew Elmore received his B.S. degree in applied physics from Purdue University in 1997. He attended Brown University where he received an MS in Geological Sciences in 1999 and a PhD in Geological Sciences in 2003. He then held research positions at the Carnegie Institute for Science in Stanford, California and at Dartmouth College. Since 2006, Dr. Elmore has been at the University of Maryland Center for Environmental Science Appalachian Laboratory where he is currently an Associate Professor. His area of expertise is in the applications for remote sensing to scientific questions at the interface of ecology, geology, and society.

Frank Liu

Frank Liu has over twenty five years of successful venture capital and private equity investment experience in the Asian Pacific region. From 1989 to 2002, he was a Director and Executive Vice-President for Transpac Capital Pte Ltd. In his current role as free-lance financial advisor, Mr. Liu continues to work in all phases of venture capital and private equity. He currently serves as a board member of Primax Electronics Ltd, China Yong Shen Ltd, and SBDMC and is a director of Taiwan M&A and Private Equity Council. Mr. Liu holds a BS in physics from the National Taiwan University, an MS in physics from Purdue University, an MS in electrical engineering from the Massachusetts Institute of Technology, and an MS in computer science from the Massachusetts Institute of Technology.

From the Director of Development

Greetings from West Lafayette!

You may have heard the news, but if you haven't, let me be the first to share it. On October 9, 2015, President Mitch Daniels announced EVER TRUE: THE CAMPAIGN FOR PURDUE UNIVERSITY.

This is an invitation to the Purdue family to join together, through private giving and personal involvement, to help arrive at answers—and, in doing so, to boldly advance our University as a national and global leader that continues to move the world forward. Spanning July 1, 2012, through June 30, 2019, this campaign is the largest fundraising effort in Purdue history, concluding in our 150th anniversary year.

OUR GOAL: $2.019 BILLION RAISED BY 2019.

This momentous endeavor will propel our Purdue Moves initiatives—Affordability & Accessibility, STEM Leadership, World-Changing Research, and Transformative Education—and reinforce our overarching commitment to keep a rigorous college education within students' financial reach. More broadly, it will unite the Purdue community around three key priorities: Place Students First, Build on Our Strengths and Champion Research and Innovation.

Your gifts to Physics and Astronomy help us achieve those goals in STEM Leadership – no matter the size! We greatly appreciate your generosity and can't thank you enough for your continued loyalty.

Ever True,

Christy Harrison, '90
Director of Development
csharrison@prf.org

Physics Degrees December 2014 - August 2015

Bachelor of Science

Vishal Bajaj
Peter Barton
Scott Blake
Carlos Blanco
Robert Bouscher
Evan Bray
Jenna Burnett
Branden Burns
Zhijie Chen
Ehren Coburn
Jack Conrad
Joshua Dandridge
Benjamin Eng
Benjamin Fasig
Connor Feeney
Daniel Fisher
Gabriel Fritz
Daniel Froemming
Christopher Gibbs
Woodrow Gilbertson
Dylan Griffith
Anna Harris
Kyle Isch
Meng Jiao
Patrick Kelley
Kamal Khan
Jeffrey Klimes
Mark Krutulis
Jennifer Larson
Mingbin Lin
Hu Li
Shaolei Li
Yanghao Luo
Bennett Marsh
Andrew Murrell
Bryan Novak
Nikola Plavsa
Kory Pritchett
Robert Schmidt
Jonathan Stelzleni
Austin Trout
Jonathan Troville
Jacob Wilson

Master of Science

Kyle Aitken
Nianpei Deng
Darren Erdman
Mawufemor Kudadze
Jingchen Liang
Tzu-Ging Lin
Shu-hao Yeh
Yucong Zhang

Doctor of Philosophy

Bradley Abell
Reza Afra
Eric Boomsma
Laura Boon
Isaac Childres
Tony Clevenger
Nianpei Deng
Qi Feng
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enough time on the surface – before burial – to accumulate a sufficient concentration of radionuclides to allow burial dating.

Establishing a chronology for these skeletal remains has been a goal of paleo-anthropologists for years and the most recent AMS measurements are Purdue researchers second attempt at determining their age. Partridge et al. (2003) reported a burial age of 4.17 $\pm$ 0.35 Myr, a surprisingly old age. The use of burial ages for this specific purpose was relatively new at this time and this old age caused considerable controversy; other techniques in fact indicated ages several million years younger.

One of the key limitations in the burial age technique has been the precision of the ^{26}Al measurement. All AMS measurements start with the production of a negative ion, produced by bombardment of the purified sample (BeO for Be and Al_2O_3 for Al) by cesium. For Be, a BeO- ion is injected. For Al, Al^- is injected. AlO^- produces a much higher current secondary ion beam but MgO^- is also produced in prodigious quantities, ultimately swamping the few ^{26}Al counts in the detector with the isobar ^{26}Mg. Mg^- is not formed so although the formation efficiency of Al^- is low, it can be measured, albeit with far less precision than ^{10}Be. The difficulty in making this measurement is well-known and undoubtedly contributed to the debate about the robustness of burial ages.

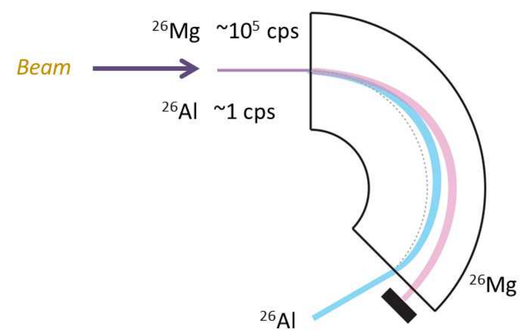

Figure 4: Schematic of gas-filled-magnet showing isobar separation

If the Mg isobar could be rejected, then AlO^- could be injected, yielding a nearly 10-fold increase in counts at the detector. To accomplish this, researchers at PRIME Lab have implemented a gas-filled-magnet on a new beam-line in front of a standard *dE/dx* detector (Figures 4 and 5). The principle behind this instrumentation is that species with differing Z will have different mean charge states as they traverse a magnetic field. In the gas-filled-magnet ^{26}Mg and ^{26}Al will each have a different radius of curvature in the sector magnet. The ^{26}Mg does not enter the detector, whereas the ^{26}Al does. Before the gas-filled-magnet, injection of AlO^- would result in MHz count rates of ^{26}Mg in the detector, effectively precluding its use. With it, a 10^5 rejection in ^{26}Mg is achieved, enabling a far more precise ^{26}Al measurement.

Figure 5: Professors Darryl Granger and Marc Caffee in front of gas-filled-magnet *(Courtesy of Purdue University/John Underwood)*

The Sterkfontein samples were re-measured using the gas-filled-magnet. The new age is 3.67 $\pm$ 0.16 Myr. Within errors this more precise measurement agrees with the older measurement. This age indicates that Little Foot is the oldest hominid remain found to date, even older than the famous Lucy remains found in Ethiopia and dated to 3.2 Myr. These ages indicate considerable complexity in the evolution of early hominids in Africa.

The implementation of the gas-filled-magnet has positioned PRIME Lab to be in the forefront of measurements of the ^{10}Be-^{26}Al pair and its application to a wide variety of problems. This instrumentation will in the near future also be used to develop measurement capabilities for radionuclides not detectable with current AMS machine, most notably ^{53}Mn. Although these radionuclides are rare in nature, the number and scope of scientific investigations using them continues to grow. With the improvements in detection sensitivity and precision enabled by the gas-filled-magnet we anticipate more innovative investigations in the upcoming years.

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