Department of
PHYSICS *and* ASTRONOMY

UNC COLLEGE OF ARTS & SCIENCES

THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

FALL 2015

NEUTRINOS AND THE NOBEL PRIZE

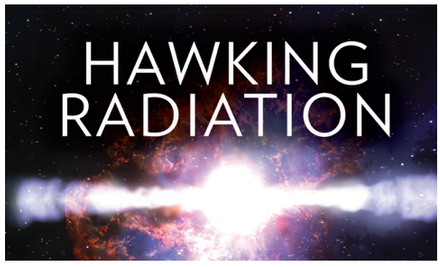
The 2015 Nobel Prize in Physics was awarded to Takaaki Kajita of the University of Tokyo and Art McDonald of Queens University in Ontario, Canada in early October for their work on neutrinos. McDonald led the Sudbury Neutrino Observatory (SNO), a project that included three members of our department. John Wilkerson, the John R. and Louise S. Parker Distinguished Professor of Physics, Associate Professor Reyco Henning, and Senior Research Scientist Mark Howe all worked on the SNO experiment before coming to Carolina.

Neutrinos are the most abundant particles in the universe but they interact very weakly with other matter and are therefore difficult to detect. Nuclear reactions in the sun should produce large numbers of neutrinos, but experiments in the 1980's and 1990's only detected about a third to one half as many neutrinos as expected. This became known as the "solar neutrino problem." SNO was designed and built to address this problem by measuring the fluxes of all the different neutrino flavors, something the early experiments could not do. In 2001 the SNO collaboration presented the first clear evidence that the solar models were correct and that it was the neutrinos that changed flavor as they propagated through space. The mixing between neutrino flavors requires that they have mass, which was not established or expected before these measurements.

Prof. John Wilkerson at the Sanford Underground Research Facility (SURF)(Photo by Benjamin Brayfield).

Wilkerson, Howe and Henning are now working on the next big question about neutrinos, which is whether they are their own antiparticles. UNC-Chapel Hill is the lead institution for a major international experiment, called MAJORANA, that will attempt to address this question.

Wilkerson also is the inaugural director of the new Institute for Cosmology and Astrophysics, Subatomic Matter, and Symmetries (CoSMS Institute), a joint physics institute headquartered at UNC-Chapel Hill and organized to work on fundamental problems at the leading edge of basic physics research. CoSMS is a partnership with Duke, NC State, and Oak Ridge National Laboratory.



Stephen Hawking and other physicists attended a conference on Hawking Radiation during the week of August 24-29 in Stockholm, Sweden. The event was initiated and co-organized by UNC Professor Laura Mersini-Houghton and was co-sponsored by the University of North Carolina at Chapel Hill, the Nordic Institute for Theoretical Physics, the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge and the Julian Schwinger Foundation. UNC Chancellor Carol L. Folt delivered remarks prior to Professor Hawking's public lecture on August 24. See article on page 3.

WHAT'S INSIDE

FROM THE **CHAIR**

Neutrinos are elusive particles and detecting them is a tricky business. Along with our CoSMS colleagues at Duke, we are celebrating the success of two different neutrino experiments, Super-Kamiokande and the Sudbury Neutrino Observatory. These experiments were led by Takaaki Kajita of Japan and Art McDonald of Canada, who were jointly awarded the 2015 Nobel Prize in Physics for their measurements showing that neutrinos undergo mixing and therefore have mass.

Chris Clemens

UNC Physics Professors John Wilkerson, Reyco Henning, and Senior Research Scientist Mark Howe of our department were part of the SNO collaboration and contributed substantially to the key discovery. They are now working on the next big question, which is whether neutrinos are their own anti-particle. We salute these and all the other dedicated neutrino physicists who labor long hours in deep mines to help discover what's missing from the standard model of particle physics. See the articles on page one and three of this newsletter for more on neutrinos.

This fall semester, we are excited to be launching an international search for a new colleague in the area of experimental nuclear physics to fill the newly-endowed Edward G. Bilpuch Distinguished Professorship in Physics. While attending UNC on a football scholarship, Ed Bilpuch played on three major bowl teams … in the Cotton, Sugar and Orange bowls. He was elected to Phi Beta Kappa and received both his BS (1950) and his Ph.D (1956) in physics from our department, and he was a member of UNC's first class of Morehead Scholars. Ed joined the physics faculty at Duke in 1962 and rose there to be the Henry W. Newson Professor of Physics. He served as Deputy Director of the Triangle Universities Nuclear Laboratory from 1966 to 1978 and as Director until his retirement in 1992.

We are grateful to Ed's widow, Marilyn S. Bilpuch, for her generous gift that has established this professorship in his honor. The new colleague we hire will conduct research at the Triangle University Nuclear Laboratories (TUNL), which celebrated its 50th Anniversary this month, and will teach in our department.

Our research and educational missions rely upon federally-funded labs, state-funded classroom teaching, and the generosity of individual donors. This powerful public-private alliance forms the backbone of great universities like Carolina. In a time when federal funding is increasingly competitive and state budgets are tight, all institutions of higher education rely greatly on private donations. We would not be the Carolina or the department that we are today without your generous commitment and support. I am truly grateful to all of our donors and hope that you will consider continuing or beginning to support the department.

With warmest regards,

Chris Clemens
Chair, UNC Physics and Astronomy

HISTORIC CONFERENCE, HISTORIC CHALLENGE

Physicists have long debated whether the information carried by particles falling into a black hole is lost from the universe forever or whether bits of this information continue to exist in some form. Thirty-two of the world's leading physicists gathered in Stockholm in late August to try to tackle this problem in fundamental physics, which is called the information loss paradox.

Six days weren't enough to solve a problem that has stumped physicists for 40 years. Still, the week-long Hawking Radiation Conference in Stockholm, Sweden was productive.

UNC-CH Chancellor Folt with Stephen Hawking and UNC Professor Laura Mersini-Houghton, who organized the conference in Stockholm.

"In science, having disagreements is considered more successful than having an agreement because that's how discoveries are made," said Laura Mersini-Houghton, associate professor of theoretical physics in the College of Arts and Sciences at Carolina and the initiator and main organizer of the conference. "Science relies heavily on scrutiny. If we all agree on one point of view, then that door is shut. There is no room left for inquiry."

"UNC-Chapel Hill has been so fortunate because we have been able to co-sponsor this historic conference with some of the greatest institutes of theoretical physics in the world," UNC-Chapel Hill Chancellor Carol L. Folt said.

A highlight of the conference came when one of the world's best-known physicists, Stephen Hawking, emeritus Lucasian Professor and Dennis Stanton Avery and Sally Tsui Wong-Avery Director of Research in the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge, announced a completely new solution to the information loss paradox.

The field of theoretical physics has changed significantly since Hawking and his contemporaries helped define it four decades ago. Mersini-Houghton wanted to bring them together for a lengthy, in-person discussion to ignite new ideas and to make sure the work in the field is passed along completely to the next generation of physicists.

"It was very important that when that group of people passes the torch to the next generation, the story of Hawking Radiation and black holes and information loss is absolutely clear, so that whoever works on this field from now on will be able to know what the correct way of thinking is," Mersini-Houghton said.

The Hawking Radiation Conference was co-sponsored by UNC-Chapel Hill along with the Nordic Institute for Theoretical Physics (Nordita); the Centre for Theoretical Cosmology at the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge; and The Julian Schwinger Foundation, co-hosted by KTH Royal Institute of Technology.

Rob Holliday, UNC Office of Communications and Public Affairs

UNC Physics *Facts*

In 2015, there are **85** graduate students in the department.

Professor Charles Evans has been named the Agnew H. Bahnson Jr. Distinguished Professor of Physics

In 2015, our department will host our first **NASA Hubble Postdoctoral Fellow, Dr. J.J. Hermes.**

In 2014, UNC was tied (with NC State University) for the **22nd** largest class of graduating seniors in physics nationwide.

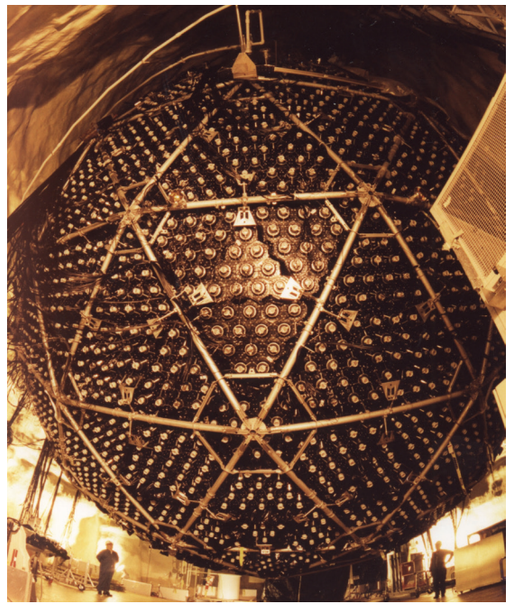
Roger Wendell, former UNC Graduate Student now Assistant Professor at the University of Tokyo, was awarded the **Young Scientist Award of the Physical Society of Japan in 2014 for work on Super-Kamiokande.**

Professor Laura Mersini-Houghton was recently featured in the BBC-Horizon documentary **'Which universe are we in?'**

PHYSICS CORNER

NEUTRINOS

In the medieval era, the search for a way to change lead into gold was the subject of alchemy, a branch of research that led through Robert Boyle and Isaac Newton to modern chemistry. We now know that the methods of chemistry cannot effect the transmutation of the elements. The energy scales of chemical reactions, which involve rearrangement of electron states in atoms, are far too low. However, in the 20th century, breakthroughs in (much higher energy) nuclear physics led to the understanding that certain elements transform into others naturally, through a process known as radioactive decay. In a common form of radioactive decay, called beta-decay, a neutron inside of an atomic nucleus spontaneously transforms into a proton, changing the element to the next higher one on the periodic table. In this decay an electron (also called a beta particle) is emitted. However, early measurements of these particles implied that the total energy was not conserved in beta-decay.



View of the SNO detector after installation of the bottom PMT panels, but before cabling (Photo courtesy of Ernest Orlando Lawrence Berkeley National Laboratory).

Wolfgang Pauli and later Enrico Fermi proposed the missing energy was carried away by a particle called the neutrino which, in 1956, was experimentally detected. The neutrino interacts so weakly with ordinary matter that it has taken a long time to measure its properties, and many of the most basic properties remain elusive. For instance, we don't know the masses of neutrinos, although experiments at Super-Kamiokande and the Sudbury Neutrino Observatory have shown that they cannot be zero. These experiments were recently awarded the 2015 Nobel Prize in Physics for their results.

> "The neutrino interacts so weakly with ordinary matter that it has taken a long time to measure its properties, and many of the most basic properties remain elusive."

Neutrinos with mass contradict the expectations of the so-called "standard model" of physics, the theoretical framework developed to understand the interaction of all particles and fields in existence. The simplest version of the standard model is therefore wrong, and the search for the best way to extend or correct it is the 21st century analog of the ancient search for a way to change lead into gold. Much of basic physics research is aimed in one way or another at this problem.

STAFF NOTES

Beverly Loftin

Cassandra Houston

Shannon Isley

Nominations recently closed for the department's second annual staff achievement awards, inaugurated in 2014 to recognize staff for superior service.

Department Manager Beverly Loftin received the first Donna Braxton Staff Excellence Award last year, while Business Services Coordinator Cassandra Houston earned Team Player of the Year. Administrative Services Manager Shannon Isley received the Personal Achievement Award.

"Anything that puts me in the center of attention makes me embarrassed," team player Houston admitted with a laugh. "But I really did appreciate the award. It's been a pleasure working with the department, serving here, and watching it grow."

Loftin suggested the idea of staff awards to department Chair Chris Clemens as a way to publically recognize staff efforts and boost morale. Associate Chair Jonathan Engel heads an awards committee that makes its decisions based on nominations from anyone in the department – faculty, staff or students. The recognition comes with a monetary bonus.

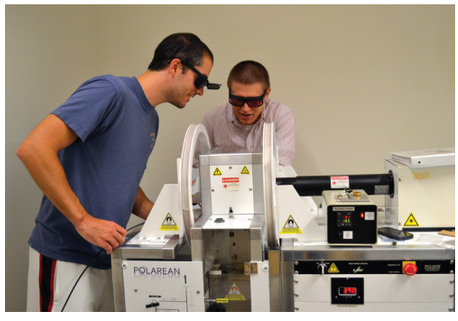
All three recipients said they appreciated their work – generally behind the scenes - being acknowledged.

"I felt accomplished – like I'd really achieved a goal," Isley said.

The 2016 awards will be announced at the department's holiday party in December.

IN THE LAB

NEW MRI METHOD DETECTS METABOLICALLY ACTIVE BROWN FAT



Graduate students Alex Burant (left) and Michael Antonacci (right) adjust an experimental MRI machine.

The recent discovery in adult humans of metabolically active brown fat, a fatty tissue specialized for dissipating large amounts of energy in the form of heat, has opened new avenues for the treatment of obesity and diabetes. But progress in studying human brown fat often has been slowed by difficulties in detecting this tissue. Now, a team of researchers in the Department of Physics and Astronomy, led by Dr. Branca, has developed a new magnetic resonance imaging method that will help researchers to clearly detect this tissue in humans with unprecedented sensitivity and specificity. This new imaging method, recently described in the Proceedings of the National Academy of Sciences, leverages the exquisite temperature sensitivity of the lipophilic gas xenon, whose nuclear polarization is enhanced up to five orders of magnitude through spin-exchange optical pumping, produce background free *in vivo* maps of brown fat and its temperature. In collaboration with UNC clinical investigators, Dr. Branca is now using this method in humans to understand how this tissue develops and how it is regulated in the body.

STUDENT SPOTLIGHT

Physics and political science major (and math minor) Drew Roberts spent the summer in Washington, DC, as a Mather Policy Intern, working with the minority staff of the US House Committee on Science, Space, and Technology.

He prepared documents and witnesses for hearings on the International Space Station, the EPA, the National Weather Service, and the DOE. He says the internship "allowed me to know that I would like to end up in the science policy world."

Student Life

NEUTRINO DAY COMES TO THE TRIANGLE

A live video tour of the MAJORANA DEMONSTRATOR cleanroom facility at the Sanford underground lab was displayed in the Daily Planet of the Museum of Natural Science during the Neutrino Day event.

This year marks the first year in a new tradition of hosting Neutrino Day in the Triangle. Hosted by UNC, the CoSMS Institute, and The North Carolina Museum of Natural Sciences, the event featured members of the UNC Physics Department both locally at the Museum of Natural Sciences in Raleigh and deep underground in the Sanford Underground Research Facility (SURF) in Lead, SD, explaining the physics of neutrinos and dark matter. The MAJORANA DEMONSTRATOR project is based at SURF (see page 1).

In its debut this year in Raleigh, Neutrino Day featured talks on neutrinos by NCSU professor and former UNC postdoctoral fellow Matthew Green and on Dark Matter by Patrick Treuthardt, assistant director of the Astronomy and Astrophysics Lab at the Museum of Natural Sciences. The event also included a question and answer session from underground at the Davis Campus of SURF led locally by UNC postdoctoral fellow Christopher O'Shaughnessy and the museum's Rachel Smith. Despite its depth nearly a mile below the surface of the earth, the SURF laboratory is actually 100 ft in elevation above the Museum of Natural Science.

Fittingly, Professor Reyco Henning and MAJORANA collaborators were remotely displayed in giant form on the interior of the Daily Planet at the Museum for this Q&A session. Visitors also viewed a live walkthrough tour of the MAJORANA DEMONSTRATOR cleanroom facility.

The event was a huge success, drawing at least 120 participants, and over 1800 at SURF in SD.

In addition to the presentations and live feed from SURF, attendees were encouraged to take part in activities and demonstrations for visitors of all ages. UNC graduate students Gulden (Joule) Othman and Chelsea Bartram helped visitors visualize radioactive decay, cosmic rays, and the challenges associated with constructing legos in a glovebox, simulating the construction of neutrino physics experiments. Thanks to the unique partnership that the new CoSMS Institute establishes between UNC and local museums, we can look forward to more great outreach programs like Neutrino Day engaging the Triangle community.

CoSMS NEWS

The Institute for Cosmology, Subatomic Matter & Symmetries (CoSMS) held a retreat May 7 at the NC Botanical Gardens in Chapel Hill. More than 40 Institute faculty from UNC, Duke, NCSU, NCCU, and Oak Ridge National Laboratory attended the retreat. The day started with a series of lively "Elevator" talks by each Institute member on their current research activities. Sessions were held to identify and discuss key science questions to be addressed in the coming decade. In the afternoon working groups addressed upcoming Institute activities and opportunities.

The CoSMS Institute is developing a series of international workshops exploring fundamental questions in physics and mathematics. The unifying theme is "From the Abstract to Practical" – translating the leading edge of fundamental theory into practical experiments and empirical observations. The overarching goal is to update the local, national and international community on progress in fundamental theory. CoSMS has received support from the UNC Office of Research to launch the inaugural workshop in this series.

We congratulate CoSMS Institute colleagues Professors Kate Scholberg and Chris Walter at Duke University who are members of the SuperKamiokande collaboration led by Taakaki Kajita who shared the 2015 Nobel Prize for Physics for the discovery of neutrino oscillations.

Department of
PHYSICS *and*
ASTRONOMY

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Phillips Hall, CB #3255
120 E. Cameron Ave.
Chapel Hill, NC 27599-3255

Non Profit
Organization
US POSTAGE PAID
Chapel Hill, NC
Permit Number 177

TUNL CELEBRATES ITS 50TH ANNIVERSARY

On November 6-8, 2015, we celebrated the 50th anniversary of the formal agreement between Duke University, NC State University, and UNC that established the Triangle Universities Nuclear Laboratory. TUNL's beginnings in the fall of 1965 coincided with the award of funds by the US Atomic Energy Commission to purchase its tandem Van de Graaff accelerator. Since then, TUNL has grown into a multi-faceted, collaborative nuclear physics research and training program with more than $7M in annual external funding. Its 280+ doctoral graduates have gone on to a wide variety of careers in the academic, government, and private sectors.

JOIN US at the forefront of physics and astronomy with a financial gift to the department.

The Department of Physics and Astronomy Excellence Fund helps enhance our world-class programs in research and education by supporting visiting speakers, providing seed funds for new instrumentation, and expanding research experiences for our students.

Gifts of any size will greatly increase our ability to support outstanding faculty and students.

To give online, visit www.physics.unc.edu/donate/

To give via check, make your check payable to "The Arts and Sciences Foundation" and include "101281 – Physics and Astronomy Excellence Fund" in the memo line. Please mail your check to:

The Arts and Sciences Foundation
134 E. Franklin Street
CB# 6115
Chapel Hill, NC