Department of
PHYSICS *and* ASTRONOMY

UNC COLLEGE OF ARTS & SCIENCES

THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

SPRING 2015

UNC LAUNCHES NEW INSTITUTE FOR FUNDAMENTAL PHYSICS

2015 is an exciting year for the Department of Physics and Astronomy as we launch the Institute for Cosmology, Subatomic Matter and Symmetries (the CoSMS Institute) in partnership with North Carolina State University, Duke University, and Oak Ridge National Laboratory. Headquartered at UNC, the CoSMS Institute will bring together the diverse research capabilities of our department and our partner institutions around a set of interconnected questions at the forefront of physics and astronomy and at the heart of our understanding of the universe.

What is the source of the observed matter-antimatter asymmetry in the universe? What is the nature of dark matter and dark energy, which according to astronomical and cosmological observations constitute the majority of matter-energy in our universe? What roles do black holes play in astronomy and in fundamental physics? What is the nature of neutrinos and what is their role in the early universe? How does the existence of dark matter, neutrinos with mass, and dark energy influence the formation of stars, galaxies, and large-scale structure?

Addressing these questions, whether by experimental measurements or new theoretical insights, requires knowledge and interactions spanning a broad set of disciplines and expertise. Spearheaded by Prof. John Wilkerson, the CoSMS Institute will build upon the combined strengths of institute faculty to forge connections among theorists who work in abstract mathematical

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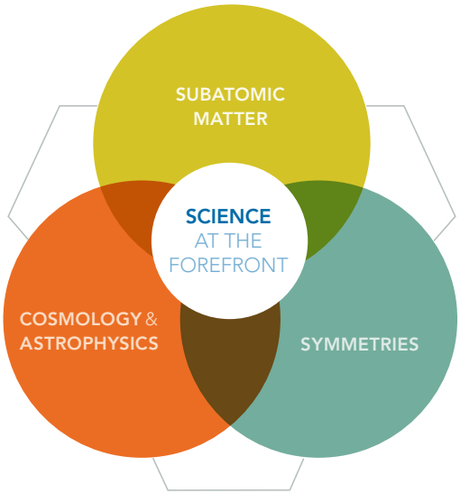

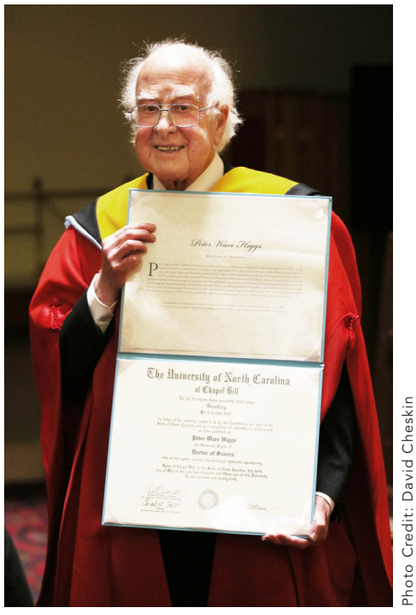

Photo Credit: David Cheskin

Nobel Laureate Dr. Peter Higgs was presented with an honorary PhD by UNC Chancellor Carol Folt on March 3, 2015. While a visitor to our department in 1965, Higgs submitted a paper in which he predicted the existence of the particle now called the Higgs Boson. See *From the Chair* (page 2) and our *Physics Corner* feature (page 3) for more.

WHAT'S INSIDE

FROM THE **CHAIR**

While a postdoctoral visitor to our department in late 1965, Dr. Peter Higgs submitted the paper "Spontaneous Symmetry Breakdown without Massless Bosons," in which he predicted the existence of a new fundamental particle, now called the "Higgs Boson" (see our *Physics Corner* feature). The paper appeared in the May 1966 issue of *Physical Review* and spurred a decades-long search for the theorized particle. In 2012, experimental physicists at CERN's Large Hadron Collider near Geneva, Switzerland announced they had discovered it. In 2013, Higgs shared the Nobel Prize in Physics with Francois Englert. On March 3rd of this year, UNC Chancellor Carol Folt presented him with an honorary PhD from the University of North Carolina.

Chris Clemens

Higgs came to Chapel Hill as a visitor to our department's Institute for Field Physics, directed by faculty members Bryce and Cecile DeWitt. A few years prior the same institute hosted the famous Chapel Hill conference on gravity and general relativity, known today as GR1 to distinguish it from 19 subsequent conferences on the subject. Peter Higgs was supposed to spend his time in Chapel Hill studying gravity but admitted "ruefully" that he spent it on symmetry breaking in quantum field theory. There is a lesson here for students and faculty alike about the importance of pursuing ideas wherever they lead, even if they do not conform precisely to administrative expectations.

Another significant lesson to draw from these events is the impact of philanthropic giving on the quality of our research program. The Institute for Field Physics was established with private gifts from Agnew H. Bahnson, whose funds helped maintain a robust visiting scientist program and sponsor numerous international conferences, effectively extending our faculty to include the global scientific community. Unfortunately, in 1971 the DeWitts departed Chapel Hill to form The Center for Relativity at the University of Texas at Austin, for reasons explained in the UT memorial resolution honoring Bryce DeWitt:

By 1970, the DeWitts had begun to think of leaving Chapel Hill. Several years earlier Bryce's title had been changed to professor while Cecile had been demoted to lecturer. In addition, upon the death of Agnew Bahnson Jr., the Winston-Salem industrialist who had founded and provided financial security for the Institute of Field Physics, and upon his widow's transfer of its backup funds to the university, the status of the Institute underwent an abrupt change. No longer was it possible to offer postdoctoral positions with the assurance that funds would be available even if grant money failed to materialize. The postdocs of earlier years had included Felix Pirani, Ryoyu Utiyama, Peter Higgs, and Heinz Pagels. This stream of talented people had now come to an end.

With this newsletter, I am happy to announce that our very distinguished Institute for Field Physics will join our research programs in astronomy, cosmology, nuclear and neutrino physics in a new institute with a broad and ambitious mission. The new Institute for Cosmology, Subatomic Matter, and Symmetries (see article on page 1) will connect field theorists with experimentalists and tool builders to work collectively on a set of interrelated questions about our universe: What is the nature of dark matter and dark energy? How must the standard model of particle physics be extended to incorporate the mysterious properties of the neutrino? From what underlying theory might the standard model emerge? I am very excited about this new institute, and optimistic that it will bring a renewal of our visitor programs, conferences, and collaborations and re-establish UNC as a regional and national leader in fundamental physics research.

We have also re-launched our department newsletter in this new format and I am grateful to our new editor, Sarah Adair, for bringing this about. I look forward to telling our alumni and friends about the exciting developments underway in our department in this and future issues.

With warmest regards,

Chris Clemens
Chair, UNC Physics and Astronomy

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realms and the tool-builders who must construct devices to extract measurements from nature.

Planned activities for the CoSMS Institute include a visiting scientist program, international conferences and workshops, and a colloquium series that will bring a steady stream of internationally renowned scientists to Chapel Hill to engage with students, faculty, and researchers. The institute will provide new opportunities for student researchers to collaborate across subfields and prepare students to tackle multi-disciplinary problems throughout their careers.

A coordinated outreach program and partnerships with local science centers—including the Morehead Planetarium and Science Center at UNC, Museum of Life and Science in Durham, and the Astronomy & Astrophysics Research Lab at the NC Museum of Natural Sciences in Raleigh—will connect institute research to the community, inspire the next generation of scientists, and provide hands-on opportunities for students to develop vital communication skills.

> **"Addressing these questions, whether by experimental measurements or new theoretical insights, requires knowledge and interactions spanning a broad set of disciplines and expertise."**

For more information on the CoSMS Institute and opportunities to get involved, contact cosms@unc.edu

UNC Physics *Facts*

In 2013-14, the department awarded an all-time record of **42** baccalaureate degrees, which places us among the top 20 or so programs nationally in class size.

We have **202** registered majors in our program, also an all-time high.

Professor John Wilkerson became Chair of the Division of Nuclear Physics of the **American Physical Society** in April 2015.

Graduate Student Graham Giovanetti has been awarded a prize postdoctoral fellowship at **Princeton**, the Dicke Fellowship.

Laurel Burk, now a postdoctoral research associate with UNC Physics and Astronomy, was named the 2014 recipient of the **Dean's Distinguished Dissertation Award for Mathematics, Physical Sciences, and Engineering.**

Professor Christian Iliadis was the university's 2014 nominee for the **Board of Governors' Award for Excellence in Teaching.**

Professor Charles Evans was recognized with a **2014 Distinguished Teaching Award** for his post-baccalaureate instruction.

Undergraduate Drew Roberts has been named a **Mather Policy Intern,** a program that sends two physics majors to Washington, DC each summer.

Professor Laurie McNeil has been named the inaugural **Bernard Gray Distinguished Professor,** recognizing her extraordinary contributions to undergraduate instruction and research at UNC.

PHYSICS CORNER

THE HIGGS BOSON

Dr. Peter Higgs (left) with UNC Chancellor Carol Folt on March 3, 2015

Photo Credit: David Cheskin

Quantum field theory (QFT) is a mathematical construction that seeks to describe the interaction of all fields and particles that exist in nature. This theory describes the vacuum as potentially containing many "fields," including some that are familiar to experience such as the electrical and magnetic fields that exert spooky forces on charged or magnetized bodies. Other fields are less familiar, including the strong force that holds nuclei together and the Higgs field. Every field has corresponding particles, which can emerge from (or descend into) the vacuum with sufficient energy. In fact, QFT describes particles as no more than excitations of the various fields.

The Higgs field was devised as a possible solution to a problem in the mathematics regulating interactions among the previously discovered fields and particles in QFT. The symmetries in the various interactions did not allow any quantity to emerge from the theory that describes a particle's mass. Without rest mass, particles like protons and electrons would travel around at the speed of light and never interact to form atoms. The Higgs field was introduced to couple mathematically to the other fields and generate terms with properties that look like inertial mass.

> **"The Higgs field was devised as a possible solution to a problem in the mathematics regulating interactions among the previously discovered fields and particles in QFT."**

The Higgs field is a doublet. One of the fields in the doublet has a non-zero vacuum energy, and if it exists in nature (as opposed to only in our math) it will be associated with a massive particle at some energy, the Higgs boson. The other field is massless and supplies the extra degrees of freedom responsible for the origin of masses of the other particles in the standard model of particle physics. In 2012, the Large Hadron Collider detected evidence for a Higgs particle at a mass of ~126 GeV/c2, about 126 times more massive than a proton.

Dr. Adrienne Erickcek

Dr. Nick Law

Dr. Jonathan Heckman

Dr. Colin Wallace

NEW FACULTY

In 2013 and 2014, the department welcomed three new tenure track professors and one new lecturer to our faculty. Assistant Professors **Adrienne Erickcek** and **Nick Law** both came to us from Toronto, CA. Erickcek is a theoretical cosmologist. Her research focuses on dark matter, dark energy, and the nature of the mysterious field that caused rapid expansion in the very high-energy-density early universe, before the big bang. Law is an observational astronomer and instrument-builder. He works primarily on exoplanet detection and characterization, and is building a survey telescope—the Evryscope—that has been featured in *Popular Mechanics*, *Nature News and Views*, and *MIT Technology Review*.

Assistant Professor **Jonathan Heckman** is a theoretical high energy physicist who came to us from Harvard University. His work centers on string theory and other mathematical frameworks that might generate features of the standard model of physics from deeper principles. Lecturer **Colin Wallace** came to us from the Center for Astronomy Education at the University of Arizona and is helping to revamp our introductory courses with the most recent best practices in active learning derived from physics education research.

IN THE LAB

ADVANCING RESEARCH ON BREAST CANCER

Led by Dr. Amy Oldenburg, scientists in the Department of Physics and Astronomy are using state-of-the-art imaging technology to advance research on breast cancer and potential treatments. In collaboration with Dr. Melissa Troester at the Lineberger Cancer Center, the Oldenburg group uses Optical Coherence Tomography (OCT) to study tumor cells and their surrounding "microenvironment," which is thought to promote tumor growth and metastasis. OCT is an investigative technique in which the light scattering of cells and tissues is depth-sectioned using near-infrared laser light. OCT is particularly useful for studying tissue culture models where traditional microscopy methods cannot probe deep enough.

As recently published in PLoS One, OCT provides excellent visualization of breast tumor cells (called "spheroids"), allowing researchers in Oldenburg's lab to identify structural attributes associated with malignant cells. In another publication in Optics Letters, Oldenburg's group showed that certain nanoparticles called plasmonic gold nanorods can be used to probe the tumor microenvironment. Future research is geared toward developing a prototype high-throughput screening platform to test the efficacy of potential anti-cancer drugs on the tumor spheroids.

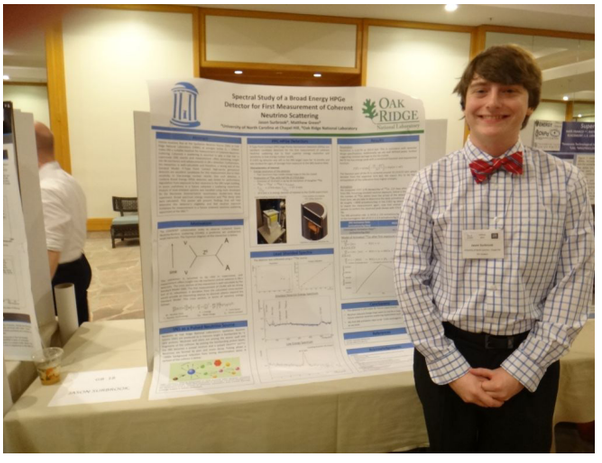


Photo Credit: Warren Rogers

STUDENT SPOTLIGHT

Physics and Astronomy undergraduate Jason Surbrook presented his research on coherent neutrino scattering at The Fourth Joint Meeting of the Nuclear Physics Divisions of the American Physical Society and The Physical Society of Japan in October 2014.

Student Life

FOR CAP REU STUDENTS, SUMMER IS A HANDS-ON EXPERIENCE

This summer, the Computational Astronomy & Physics (CAP) Research Experiences for Undergraduates (REU) program will welcome ten outstanding undergraduate students from across the country to UNC. The CAP program was launched in 2011 and has since provided both UNC and nationally recruited students with hands-on research experiences each summer. In ten short weeks the students learn computational methods in python and linux and complete individual research projects in diverse subfields such as biophysics, quantum thermodynamics, astronomy, and particle astrophysics.

CAP students engage in a variety of enrichment and social activities. Past cohorts have presented their research for such tough audiences as faculty judges for a joint UNC-NC State poster session and curious kids at the Morehead Planetarium & Science Center and the NC Museum of Natural Sciences. Interactive tours have exposed students to state-of-the-art campus facilities for 3D visualization, video production, and remote observing with the SOAR telescope. CAP workshops are designed to prepare students to apply for graduate school and write competitive fellowship applications, while trips to hiking trails and amusement parks allow students to experience the Triangle area.

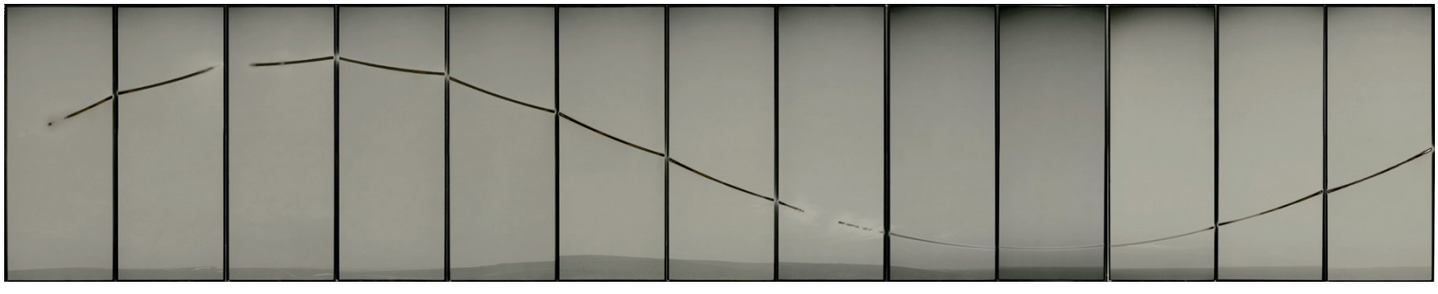
The first two nationally recruited CAP cohorts have shown a strong interest in attending UNC for graduate school, making up 20% of our first-round admitted students this year. Our own UNC students generously beta-tested the proto-REU program in 2011-2012 and several are now applying for or pursuing computational research in graduate school. In the future, the CAP program would like to develop a model including more UNC students alongside national recruits.

Directed by Prof. Sheila Kannappan, the CAP program is a community effort. Numerous UNC professors, postdocs, graduate students, and staff from the departments of Physics & Astronomy, Math, and Computer Science have given their time to the program.

The first national CAP REU cohort (pictured above) in summer 2013 produced one current NSF Fellowship winner who is now a 1st year UNC grad student and six currently accepted prospective UNC graduate students (including two NSF Fellowship applicants, one Royster Society of Fellows awardee, and one Goldwater Scholar).

THE ART OF PHYSICS: SUNBURN

Students in a summer internship program in the department's Abraham Goodman Laboratory for Astronomical Instrumentation modified a mechanical 1912 Cirkut panoramic camera to track the sun for artist Chris McCaw. The team of undergraduates, graduate students, and high school interns worked for several weeks on mechanical design, electrical circuits, programming a Raspberry Pi computer, and then integrating and documenting the modified device so it can help McCaw produce continuous versions of his Sunburn–style images. Below, a discontinuous Sunburn-style image by Chris McCaw.



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HIGH TECH CLASSROOM MAKES LEARNING MORE INTERACTIVE

This spring, students had the first opportunity to use newly renovated Phillips 335. The former library and storage space was overhauled to create a more collaborative learning environment, which features round tables, moveable podiums, and portable wipe boards that can project to a larger screen. Both physics and math courses are taught in the space.

Photo by Lauren Daly/The Daily Tarheel

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:

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