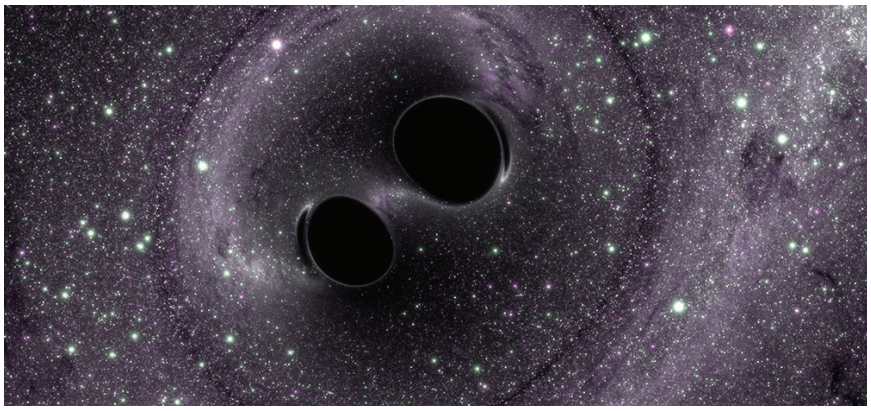
Department of
PHYSICS *and* ASTRONOMY

UNC COLLEGE OF ARTS & SCIENCES
THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

SPRING 2016

GRAVITATIONAL WAVES!



SXS, the Simulating eXtreme Spacetimes (SXS) project

On September 14, 2015, the twin detectors of the Laser Interferometer Gravitational-wave Observatory (LIGO), located in Livingston, Louisiana, and Hanford, Washington, both measured a gravitational wave signal arriving at the Earth from a distant violent merger of two black holes. The event, dubbed GW150914, marked the first time gravitational waves have ever been directly detected and the first time a black hole binary has been found and observed to merge.

LIGO scientists estimate that the initial black holes had masses of 36 and 29 times the mass of the sun, and that the event took place at a distance of 1.3 billion lightyears from Earth. The two black holes were observed to merge into a single, final black hole with a mass of 62 solar masses and a final spin equal to 70% of the maximum angular momentum that a Kerr black hole can attain. In a few hundredths of a second, the event converted three solar masses of orbital binding energy into gravitational waves. During that short interval, the peak power output was about 50 times that of the whole visible universe!

The event registered in Livingston 7 milliseconds before it appeared in the Hanford detector, consistent with the 10 millisecond maximum time-of-flight delay between the two parts of LIGO. That measured delay helps pin down the source location to a region in the southern hemispheric sky.

LIGO's historic observation of GW150914 provides two confirming tests of Einstein's 1915 discovery of general relativity (the relativistic theory of gravity). The event signaled the birth of a rotating (Kerr) black hole, the mathematical description of which was discovered by Roy Kerr in 1963. It also confirms the existence of gravitational waves—ripples in the fabric of spacetime—which were originally predicted by

(continued on page 2)

UNC Physics and Astronomy Professor and Associate Chair of Diversity, Sheila Kannappan (left), was among four university leaders who received the University Award for the Advancement of Women for 2016. The award, which was introduced in 2006, recognizes significant accomplishment in mentoring, recruiting, offering professional development, or elevating the profile of women within the university. The winners were recognized by Chancellor Carol L. Folt on March 4, 2016.

WHAT'S INSIDE

FROM THE **CHAIR**

The world of astrophysics got a lot more interesting in February with the announcement of direct detection of gravitational waves. The elegant mathematical equations for gravity that Einstein first wrote down in 1915 allowed wavelike solutions. The LIGO detection (see article page 1) confirms again the power of this mathematical theory. It also reveals that massive black hole binaries exist and that their effects on spacetime can reach our detectors here on earth. The first optical telescope built by Galileo Galilei (1610), and the first radio telescope built by Karl Jansky (1932), led to bursts of new discoveries, and we should expect nothing less for LIGO, the first successful gravitational wave telescope.

Chris Clemens

This newsletter will be my last as chair of the department of physics and astronomy. At the request of Kevin Guskiewicz, dean of the College of Arts & Sciences, I have agreed to move to South Building, where I will serve as senior associate dean for natural sciences and mathematics in the college. I look forward to working with all the science programs in Arts & Sciences, but I will miss my role in this department. I'd like to say goodbye by thanking everyone who helped me over the past four years, but especially our excellent business manager, Beverly Loftin, and associate chairs Frank Tsui, Jon Engel, Chuck Evans, Sheila Kannappan, and Sean Washburn. I will still spend many nights in Chapman Hall, using the Constance and Leonard Goodman Remote Observing Center to conduct observations of white dwarf stars and exoplanetary rubble with my graduate students Josh Fuchs and Erik Dennihy, and postdocs Bart Dunlap and J. J. Hermes. Thank you all for your help and support.

Best Wishes,

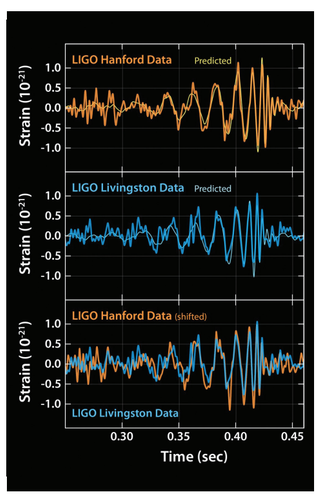
Chris Clemens
Chair, UNC Physics and Astronomy

(continued from page 1)

Einstein himself in 1916. The detection, in 2015, was a marvelous capstone on the 100th anniversary of general relativity!

The LIGO detectors are amazing technical accomplishments. They are the world's most accurate rulers, able to measure changes in distance as small as 10^{-19} meters across their 4 kilometer arm lengths. This is a change as small as one-ten-thousandth of the diameter of a proton! GW150914 made it a bit easier, by providing a signal-to-noise ratio of 24. With the advent of the era of gravitational wave astronomy, we can now look forward to many more such events as LIGO, and its international cousins, reach their full design sensitivities over the next few years.

Locally, UNC professor Charles Evans and his students mathematically model merging black holes and their emitted gravitational waves. Professors Nick Law, Dan Reichart, Chris Clemens, and Evans hope to use UNC telescopes (Evryscope, PROMPT, and SOAR) to search for electromagnetic counterparts to LIGO events.



ILIADIS NAMED PHYSICS & ASTRONOMY CHAIR

The Dean of the College of Arts & Sciences, Kevin Guskiewicz, has named Christian Iliadis to be the next Chair of Physics & Astronomy. Christian is a nuclear astrophysicist, who studies nucleosynthesis and energy production in stars. Dr. Iliadis will replace Dr. Chris Clemens, now Senior Associate Dean for Natural Sciences, on May 1.

UNC Physics *Facts*

Five researchers in our department shared in the **2016 Breakthrough Prize in Physics** for "fundamental discovery and exploration of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the standard model of particle physics." They are John Wilkerson, Reyco Henning, Mark Howe, Hugon Karwowski, and Ryan Rohm. The prize recognizes their contributions to the SNO and KamLAND collaborations.

Dr. Chris Hughes, a Physics and Astronomy professor and director of the Materials Science Center at James Madison University, recently received Virginia's highest faculty honor, an Outstanding Faculty Award by the State Council of Higher Education of Virginia. Dr. Hughes earned his PhD from UNC in 1993.

Four undergraduates from UNC Physics and Astronomy were inducted into Phi Beta Kappa at their induction ceremony on November 9, 2015: Robert Alfredson, Adam Kunesh, Enrique Toloza, and Mitchell Young.

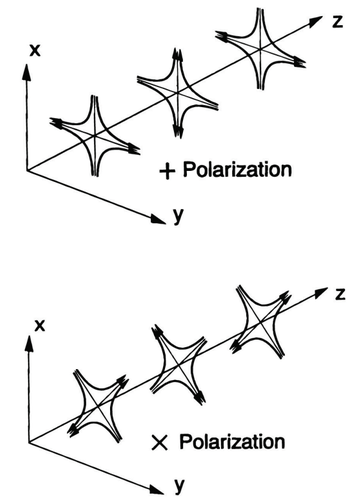
UNC Physics and Astronomy professor Nick Law and his Evryscope research were part of two proposals that received "scialog" awards from the Research Corporation for Science Advancement.

PHYSICS CORNER

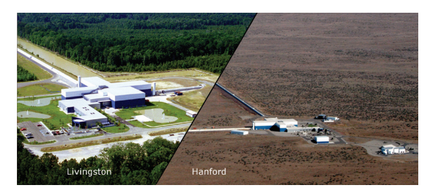
GRAVITATIONAL WAVES: RIPPLES IN SPACETIME

Gravitational waves are distortions or "ripples" in the fabric of spacetime caused by violent high-speed accelerated motion of massive bodies. Gravitational waves share some characteristics with familiar electromagnetic waves: both (1) propagate through space at the velocity of light, (2) are "transverse" to the direction of propagation, and (3) have a pair of polarizations. But beyond that, the similarities end. The electric field in an electromagnetic wave couples to the charge of particles it passes and directly accelerates those charges in the plane transverse to the direction of propagation. A gravitational wave is a propagating strain in the metrical properties of space. It couples to all particles with mass or energy and produces a relative fluctuation in the proper separation between pairs of objects in the transverse plane.

Gravitational waves are a natural consequence of the relativistic nature of Einstein's general relativistic theory of gravity and were predicted by him in 1916. Because the gravitational force is the weakest of the four forces in nature, gravitational waves are exceedingly difficult to generate and detect. Only the most violent processes, like black hole and neutron star mergers and the Big Bang itself, produce signals strong enough to be observed.



The transverse motions induced by a gravitational wave. A gravitational wave propagating in the z-direction distorts spacetime in the x and y directions, which makes particles move as indicated by the arrows.



The twin LIGO detectors. A passing gravitational wave stretches and compresses the optical path length in the 4-km arms of LIGO. These deflections are so small that they must be measured by laser interference, and still the shift is only 10-13 of a wavelength of light, or 1/10,000 of a proton diameter.

"Because the gravitational force is the weakest of the four forces in nature, gravitational waves are exceedingly difficult to generate and detect."

NEW STAFF MEMBERS

Jeannie Cox

Dylan DeLisle

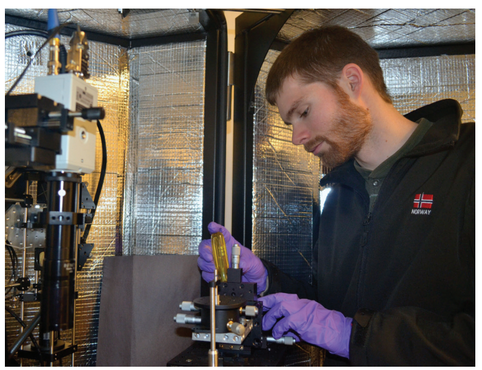
In recent months, the department has welcomed two new staff members: Academic Affairs Coordinator Dylan DeLisle and Research Associate Jeannie Cox.

DeLisle, a graduate of Tulane University, worked as a service-learning assistant while an undergraduate, helping other students navigate two semesters of service-learning assignments. Her interview for the Academic Affairs position convinced her she would like working with her staff colleagues as well as enjoying her job duties here, she said.

Cox moved to the department from UNC's School of Medicine, where she managed the residency program. Now, she's tasked with supporting Professor John Wilkerson and his work as the inaugural director of the Institute for Cosmology, Subatomic Matter & Symmetries – the CoSMS Institute.

Her work for the institute - which was organized to forge connections between scientists at UNC-Chapel Hill and other institutions - allows Cox to combine experience supporting research with an interest in physics, she said. The work gives her a view of leading research, as she helps organize events such as a March talk by Patrick Brady, a member of the LIGO consortium that recently detected gravitational waves.

IN THE LAB



Graduate Student Evan Nelsen, working with graduate student Kellie Beicker in the Superfine research group, is adjusting the optics on a new microscopy technique that is capable of viewing live biological cells from the side, simultaneous with measuring forces from individual molecules. Cells are capable of sensing and applying forces, often through individual proteins that reside on their surface. In addition, forces can be transmitted from the cell membrane to the nucleus, where they affect the proteins the cells produce and even the very identity of the cell. Evan and Kellie's new microscopy technique will provide unparalleled insight into this force transmission and activation in cells. Application of this work will deepen our understanding of the processes of infection, of cell motility, and of the mechanisms of cancer.

STUDENT SPOTLIGHT

Carisa Miller is a graduate student in Professor Adrienne Erickcek's group who dares to ask the question "is Einstein's theory of general relativity a complete description of gravity?" Although general relativity accurately describes gravity within the Solar System and successfully predicted the existence of gravitational waves, it cannot explain the current accelerated expansion of the Universe. Carisa explores how other gravitational theories behave during the Universe's first minute to determine if they are viable alternatives to general relativity.

CoSMS NEWS – SPECIAL VISITORS, COLLOQUIA, AND WORKSHOPS

The Institute for Cosmology, Subatomic Matter & Symmetries (CoSMS) is hosting several visitors during the Spring 2016 semester. Prof. Patrick Brady, the Director of the Leonard E. Parker Center for Gravitation, Cosmology, and Astrophysics, at the University of Wisconsin-Milwaukee, and a long standing member of the LIGO team, recently visited and presented a colloquium on the exciting new LIGO result to a full house of CoSMS faculty, students, and guests. Allen Caldwell, the Director of the Max-Planck Institute (Werner Heisenberg Institute) in Munich will be visiting at the end of March and speaking on the AWAKE experiment underway at CERN that is studying novel acceleration technology based on plasmas.

The Institute, with support from both the UNC Office of Research and the College of Arts and Sciences, is launching its inaugural series of international workshops "From the Abstract to Practical." Professors Christian Iliadis (UNC) and Richard Longaland (NCSU) have organized an April workshop titled **Thermonuclear Reaction Rates**, which aims to build a bridge between cosmic phenomena such as the Big Bang, classical novae, and the formation of globular clusters and their underlying nuclear physics processes.

Upcoming workshops currently in the planning stages for later in 2016 include **Naturalness and String Theory after the Higgs**, (organizers Professors Jonathan Heckman and Louise Dolan (UNC), Michael Dine (UC Santa Cruz), and Gordon Kane (U Michigan, Ann Arbor)) as well as a workshop addressing **Theoretical issues with coherent neutrino scattering** (organizers Professors Kate Scholberg (Duke), Gail McLaughlin (NCSU), Jonathan Engel (UNC), and Wick Haxton (University of California, Berkeley)).

Please send an email to cosms@listserv.unc.edu if you would like to be included on the Institute's mailing list that announces upcoming events.

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PHYSICS DONOR FUNDS AT WORK

Left to right: ***Top row,*** Joelle Dick, Emilee Armstrong, Christina Cellner; ***Second row,*** Olivia McAuley, Chiara Salemi, Mikaela Orbon; ***Third row,*** Samantha Pagan, Grace Li-Haug, Maryam Kazemzadeh-Atoufi; ***Bottom row,*** Carolyn Liu, Callie Hood, Kristy Sakano

Thanks to the J.R and M.T. MacDonald Fund in Physics, given in honor of former department chair Sang-il Choi, a group of UNC undergraduates were able to attend the Conference for Undergraduate Women in Physics (CUWiP). CUWiP allows undergraduate women to explore the different branches of physics and provides a way for them to network within the physics community. UNC students were able to ask questions to Ginger Kerrick of NASA, the keynote speaker, via a live feed. There are different locations for the conference; this year, the Old Dominion University site permitted students to tour the Jefferson Lab, where they learned about lasers and high-energy particle accelerators.

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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.

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