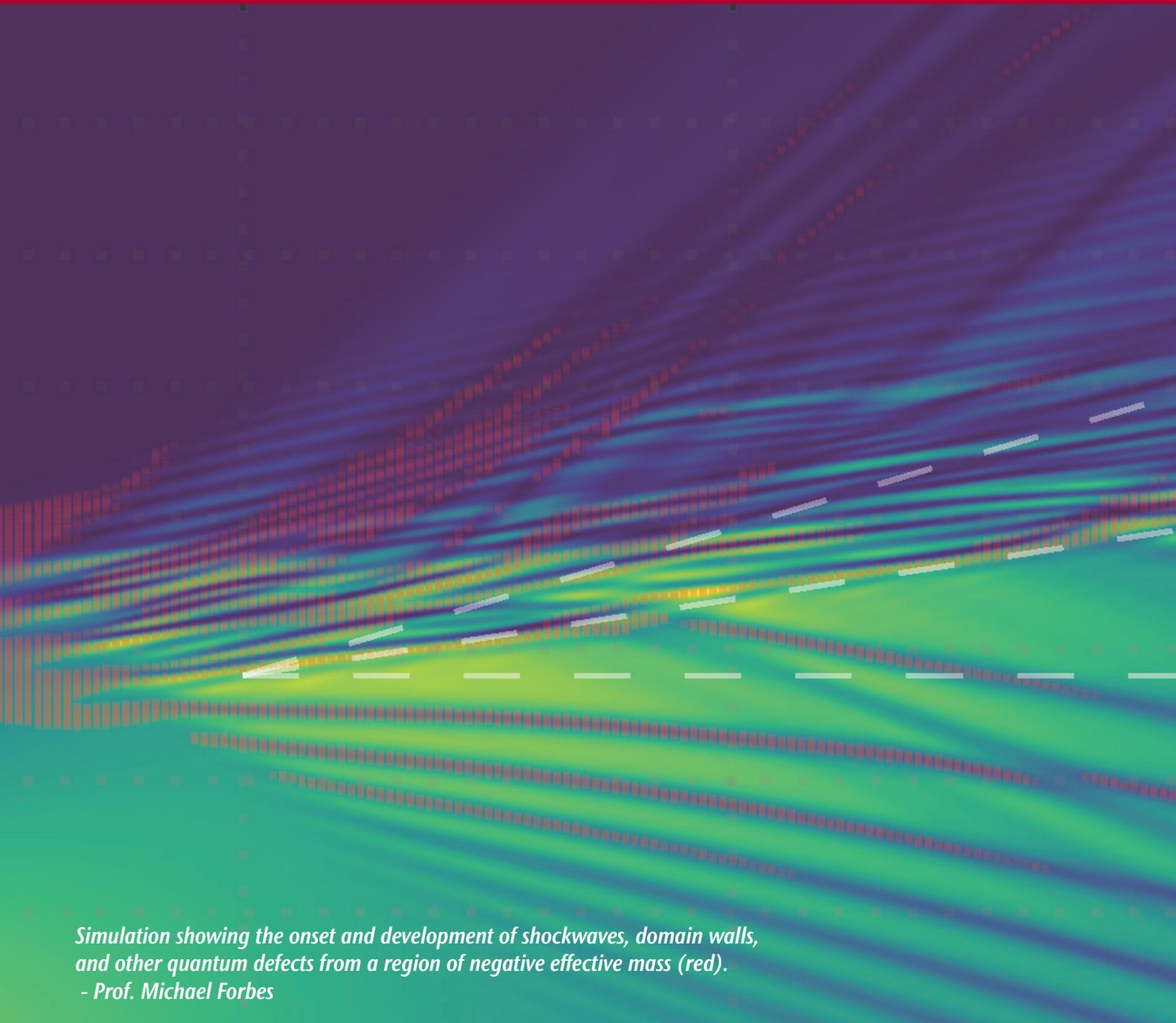


PHYSICS MATTERS

Vol. 18 • 2017-2018 • Washington State University
Department of Physics & Astronomy • physics.wsu.edu



*Simulation showing the onset and development of shockwaves, domain walls, and other quantum defects from a region of negative effective mass (red).
- Prof. Michael Forbes*



Department of

Physics and Astronomy

WASHINGTON STATE UNIVERSITY

INSIDE THIS ISSUE

PG 2

- New Faculty
- New Staff
- Retirements

PG 3

- Faculty / Staff Highlights

PG 4

- Student Highlights

PG 5

- Graduates
- Alumni Update

PG 6

- Donor Highlight

PG 7

- Club Highlights

PG 9

- WSU Scientists Help Detect Gravitational Waves for Third Time

PG 11

- WSU Physicists have Created a Fluid that Behaves as if it has Negative Mass

PG 13

- Ultracold Atoms in Space

PG 14

- Fall 2018 Events

A MESSAGE FROM THE CHAIR

Dr. Brian Saam

According to data from the American Institute of Physics that covers 2011-2015 (aip.org/statistics/washington), companies in the state of Washington that hire physics majors include Google, SpaceX, X2 Biosystems, and the Seattle Children's Research Institute, not to mention our Pullman neighbor, Schweitzer Engineering. At a conference on building thriving undergraduate physics programs that I attended with two of our faculty members earlier this year, we learned that survey data show that physicists hired by engineering firms struggle at first in adapting to the engineering culture, but that their critical-thinking and broad problem-solving skills eventually move them up to leadership positions at a relatively faster rate than their more numerous counterparts with engineering degrees.



We need to do a better job communicating to our students the broad value of our major. For those intent on pursuing graduate school in physics or astronomy, we have always prepared students well, and it's my responsibility to see that we continue to do so. However, the skills and training imparted to students by our world-class faculty can uniquely inform their further training and careers as engineers, entrepreneurs, lawyers, doctors, diplomats, and politicians. Recently, the number of majors in our undergraduate program has increased significantly; we've just enrolled 35 students in our first-year seminar course, now redesigned to better integrate prospective majors into the department through more direct engagement with our faculty and a better view of how they can become involved in research. Statistically, only a small fraction of these students will go to graduate school in physics or astronomy; our challenge is to retain these students in the major, not just by training them well, but by showing them the tremendous and varied opportunities that skills in critical thinking, mathematical modeling, and data analysis can provide to them after graduation.

Before arriving at WSU in February 2017, I was excited to join the department for many reasons, among them the exceptionally talented faculty, outstanding graduate and undergraduate students, the beauty and richness of the surroundings, and the prospects to grow and strengthen the department. A year and a half later, despite some financial challenges that have affected the entire university, I remain just as optimistic and enthusiastic, if not more so. I believe fundamentally in the role of the university in generating new knowledge, building and strengthening democracy, and preparing our students to thrive in a global economy. I'm particularly proud to be at a land-grant institution, and to accept the unique mission and additional responsibilities that this entails. The excitement around our growing undergraduate program is just one dimension of my hope for the future of WSU Physics & Astronomy; I'll write more about other aspects of my vision for the department in future columns.

OUR NEWEST FACULTY



Dr. Jeffrey McMahon started with the department in Fall 2015 as an Associate Professor. Dr. McMahon received his PhD from Northwestern University in 2010 and served as a Postdoctoral Fellow, R&D

Manager and Visiting Scholar prior to joining WSU. His main focus of research is computational condensed matter physics, although his interests are highly interdisciplinary, involving ideas from fields including physics, materials science, chemistry, and even computer science.



Dr. Brian Saam joined the department in Spring 2017 as Professor and Department Chair. Dr. Saam received his PhD from Princeton University in 1995 and served as an Assistant to Full

Professor with the University of Utah prior to WSU. Dr. Saam is an experimental atomic, molecular, and optical physicist who specializes in spin physics and magnetic resonance in a variety of gas-phase and solid-state systems.

WELCOME NEW STAFF MEMBERS



Jacob Turner
Director of Undergraduate Laboratories
Jacob brings a lot of experience with running laboratories along with a wealth of expertise in current physics education

research and best practices. Jacob comes to us from the University of Idaho where he was most recently Physics Director of Laboratory Education.

RETIREMENTS



Steve Langford
Director of Undergraduate Laboratories
32 years of service to WSU



Tim Whitacre
Instructional Support Technician 3
14 years of service to WSU

Dr. J. Thomas Dickinson
Regents' Professor

Dr. Dickinson served as a faculty member of the Department of Physics and Astronomy for 49 years. In that time he served as the major advisor for 24 Masters students and 16 PhD students, as well as taught 294 undergraduates that received their bachelor's degrees in Physics and countless students that took lower division physics courses from other majors. Dr. Dickinson had a strong research program for over 40 years, is known throughout the scientific community, and he has been elected Fellow to five scientific societies. In addition to his teaching and research accomplishments, he has provided many years of service to WSU and the greater scientific community through active participation on various committees and boards and invited talks throughout the world. We celebrated Dr. Dickinson's career with a reception in April 2017 where many of our faculty, staff, alumni and friends shared what a large impact Dr. Dickinson has on their lives and careers.



FACULTY / STAFF HIGHLIGHTS

2018 EMINENT FACULTY AWARD



Dr. Mark Kuzyk
Regents' Professor

2017 DOE EARLY CAREER AWARD



Dr. Brian Collins
Assistant Professor

GRANTS AWARDED

NEWLY AWARDED

Dr. Brian Collins	DOE Early Career Award	“Polarized Resonant X-ray Scattering to Measure Molecular Orientation and Conformation in Organic Nanostructures”	\$750,000	5-year
Dr. Michael Forbes	NSF / PHY Award	“Quantum Dynamics with Cold Atoms”	\$240,000	3-year
Dr. Brian Saam	NSF / PHY GOALI Award	“Resolving Outstanding Questions in Spin-Exchange Optical Pumping of 129Xe”	\$422,295	3-year
Dr. Gary Collins	NSF / DMR Award	“Partition of Solute Atoms Among Sublattices in Intermetallic Compounds”	\$408,278	3-year
Dr. Matthew Duez	NSF / PHY Award	“Mergers, stars, and disks: Dense matter phenomena in numerical relativity”	\$180,000	3-year
Dr. Matthew McCluskey	NSF / SBIR Phase II	“Spectroscopy and imaging of irregular surfaces using confocal microscopy”	\$739,626	2-year

CONTINUING GRANTS

In addition to the new awards above, we have **10 awards** with ongoing funding, for **8 faculty** principal investigators, totaling **\$7.62M**

STUDENT HIGHLIGHTS

SCHOLARSHIPS & AWARDS

Undergraduate Students

Paul A Anderson Prize - **Kenny Haak**

Paul A Bender Scholarship - **Simon Carter**

Miles & Muriel Dresser Fund - **Andrew Cannon**

La Rue Family Scholarship Fund - **Sterling Smith and Trevor Foote**

Text Book Scholarships

Michael Anderson

Austin Biaggne

Zachary Croft

Trevor Foote

Kenneth Haak

Korey Mercer

David Morin

Cassandra Phillips

CAS Summer Minigrant - **Trevor Foote and David Morin**

Dickinson Summer Research Award - **Drew Cannon and Leah Snyder**

NASA Space Grant Scholarship - **Trevor Foote**

2018 Showcase for Undergraduate Research and Creative Activities (SURCA) Award - **Michael Anderson and Kenny Haak**

Travel Grant to attend the Emerging Researchers National (ERN) Conference in Science, Technology, Engineering and Mathematics - **Becka Oehler**

2017 Blake Lilly Prize - **Physics & Astronomy Club**, for the chapter's outstanding outreach efforts

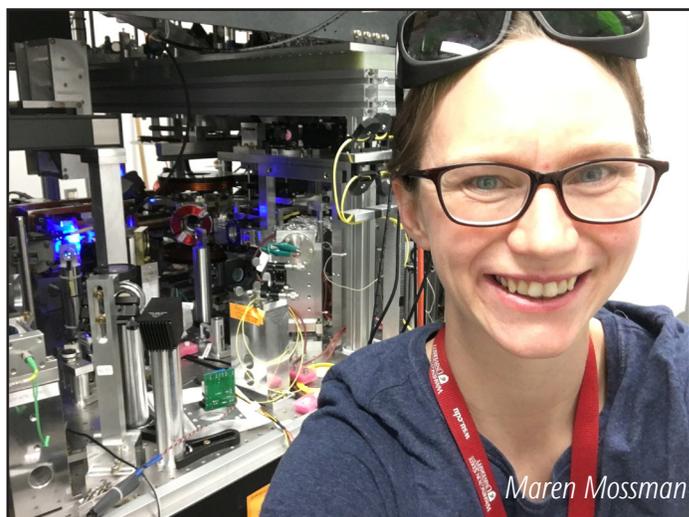
Graduate Students

Golding Fellowship Award - **Maren Mossman**

Radziemski Graduate Fellowship - **Khalid Hossain**

NASA Space Grant - **Jerred Jesse and Thomas Ferron**

2nd prize for the Best Student Paper in Underwater Acoustics at the Joint Meeting of the Acoustical Society of America and the European Acoustics Association – **Aaron Gunderson**



Maren Mossman



Christoph Tanner, Club President, @ Jefferson Elementary

CONGRATULATIONS GRADUATES!

BS

- Michael Anderson
- Zachery Bartlett
- Austin Biagne
- Zachary Croft
- Timothy Fu
- Kenneth Haak
- Skylar King
- Dylan Ward

MS

- David Buckley, Summer 17
- Islam Khan, Fall 17
- Nathan Turner, Fall 17
- Jesus Caro, Spring 18
- Dmitri Saberi, Spring 18
- Craig Tenney, Summer 18

PhD

- Wyatt Brege, Summer 17
- Qingze Guan, Summer 17
- Sean Mossman, Summer 17
- Elizabeth Bernhardt, Spring 18
- Joe Lanska, Spring 18
- Jizhou Li, Spring 18
- Liangliang Yang, Spring 18
- Shengwen Zhou, Summer 18



ALUMNI UPDATE

Aaron Van Pelt (MS, 2000; advisor: Sue Dexheimer) is Senior Director of Product Development & Innovation at Picarro (Santa Clara, CA) where he is responsible for definition and market development of cavity ringdown spectroscopy-based analyzers and data analytics for the energy industry. He leads a team of hardware, software and analytics engineers focused on solutions for methane emissions reduction, natural gas leak detection and pipeline integrity management.



Erin Craig (BS, 2002) is an Assistant Professor of Physics at Central Washington University. She enjoys teaching a variety of physics classes and mentoring undergraduate research students in computational biophysics projects.

Fran Morrissey (MS 2003, PhD Materials Science 2007; advisor: Sue Dexheimer) recently joined Lawrence Livermore National Laboratory (LLNL) in Livermore, CA, as a senior technical staff member. Currently he is developing methods for modeling laser pulse grating compressors in support of the Advanced Radiographic Capability (ARC), which is a petawatt-class laser system used to generate high-energy x-rays for backlighting implosion targets at the National Ignition Facility (NIF).



Brett Deaton (PhD 2015; advisor: Matt Duez) was recently hired by Schweitzer Engineering Lab to design and teach week-long STEM classes for employees.

What's your story? If you would like to share where you are and what you are doing send us an email at: physics@wsu.edu

DONOR HIGHLIGHT

Bobbie Riley (BS 2009) & Kevin Daily (PhD 2012)

Bobbie Riley, now an IT Services Coordinator at University of Illinois, and Kevin Daily, a Junior User Interface Developer at Wolfram Research, have been generously donating to the department for many years now. They concentrate on donations that will improve the education of our undergraduate students and have donated computers, a 3-D printer, and textbooks for our students. In 2017, they donated to upgrade the Physics & Astronomy Tutoring Center in Webster Hall. We now have an inviting, clean and collaborative space and the use of this room has increased dramatically over the last year. This summer, Bobbie and Kevin have donated to upgrade one of our departmental classrooms. Out with the old wooden desk-chair with no space for a book and paper on the same surface and in with the tables and chairs that can be arranged for lecture or collaborative work.

We are so excited to offer our students a cleaner more modern learning environment. Be sure to stop by and check out these new spaces when you are on campus!

Webster 329
Physics & Astronomy Tutoring Center



Webster 946 Classroom



CLUB HIGHLIGHTS

SOCIETY OF PHYSICS STUDENTS - WSU CHAPTER



The Physics and Astronomy Club (SPS WSU Chapter) had a busy year! They kicked off the year with demonstrations and information at the Week of Welcome Events and All Campus Picnic. The club hosted the 13th Annual Pumpkin Drop during WSU's Dad's Weekend where campus and the community at large attended to observe physics demonstrations, play physics games and decorate pumpkins before watching their pumpkins drop from the 12th floor of Webster Hall – this was even shown on ESPN's highlights for the week's football game.

A group of club members attended the APS Conference for Undergraduate Women in Physics in January.

"Attending CUWiP was an amazing experience. It allowed us to meet and network with other female Physics undergraduates across the Pacific Northwest region. Not only did we make new friends, learned valuable information about applying and succeeding in Graduate Schools, it gave us access to an inclusive community where we can all thrive and succeed." – Chamithri Adrikarige, Club Secretary.



Spring activities included hands-on demonstrations at the Kids' Science and Engineering Day, hosted by the WSU Society of Women Engineering, for grades K-9, a trip to the WSU Nuclear Science Center Reactor, and visits to our area elementary schools with hands-on physics activities. WSU Mom's Weekend marked the second year the club hosted the Egg Drop, similar to the Pumpkin Drop the community is invited for demonstrations, physics games, plus they are able to design and construct methods to protect an egg from cracking while being dropped from progressively higher elevations in Webster Hall. The group visited LIGO Hanford for tours and lectures.

The club is excited for another year of fun activities and guest speakers!



INTERNATIONAL SOCIETY FOR OPTICS & PHOTONICS (SPIE) STUDENT CHAPTER - WASHINGTON STATE UNIVERSITY

Careers in Physics Lectures

In this program, the club invites physicists from various occupations to speak about the path they took to their career. The purpose of the series is to inform graduate students about the various jobs available to one with an advanced degree in physics. A particular focus has been on job opportunities outside of the standard academic track. This year's presentations included Shoresh Shafei, Data Scientist, Marcus Knudson, National Lab Staff Scientist and Chris Hamner, Laser Physicist.



OSA/SPIE Visiting Lecturer

In January, the club sponsored a visit from Lahsen Assoufid, a Fellow of the Optical Society of America and an x-ray scientist at the Advanced Photon Source at Argonne National Labs. His colloquium was about the challenges in the future of x-ray optics that are unique to x-ray optics. For example, the fact that x-rays require a very shallow angle of incidence to be reflected by normal (low Z) materials presents interesting challenges for x-ray optics.

In February, the club hosted Harry J. Levinson. As the senior director at Global Foundries Inc. he brought an interesting perspective of an individual who had transitioned from a technical position to one with a leadership slant. His talk entitled, "Future Trends in Lithography for Fabricating Integrated Circuits," gave everyone a brief introduction to lithography and described how the future trend of using extreme ultraviolet wavelengths of light to create smaller and smaller features introduces several interesting problems with no analog in the optical wavelength techniques.

Palouse STEM Coalition

This year the club helped get an exciting initiative called the Palouse STEM Coalition started. The aim was to bring educators from all over Whitman and surrounding counties together to coordinate STEM outreach.



2018 Palouse Family Fair

The club presented demonstrations at the Palouse Family Fair, a large family-oriented event which seeks to bring contact between area organizations and families from the surrounding area.

Recruitment Activities

The club participated in several activities to encourage and recruit new graduate and undergraduate students to Physics and Astronomy. These included sponsoring the department's Welcome Back Picnic, participating in WSU's Meet your Major Fair, and hosting several events at the annual Graduate Student Recruitment weekend.



WSU SCIENTISTS HELP DETECT GRAVITATIONAL WAVES FOR THIRD TIME

By Will Ferguson, College of Arts and Sciences



An artist rendering of two black holes merging, like the ones LIGO detected. Image courtesy of LIGO.

Three billion years ago in a distant galaxy, two massive black holes slammed together, merged into one and sent space-time vibrations, known as gravitational waves, shooting out into the universe.

The waves passed through Earth and were detected early this year by an international team of scientists, including WSU physicists Sukanta Bose, Bernard Hall and Nairwita Mazumder.

The newfound black hole, first reported in the journal *Physical Review Letters* in June, has a mass about 49 times that of the sun. The collision that produced it released

more power in an instant than is radiated by all the stars and galaxies in the universe at any moment.

Findings from this and two previous discoveries of black hole mergers are providing the WSU scientists and colleagues at the Laser Interferometer Gravitational-Wave Observatory (LIGO) an unprecedented glimpse into the early universe and shedding new light on how binary black holes form. The researchers are using data from the three detections to subject Einstein's theory of general relativity to increasingly stringent observational tests. So far, however, there is no indication that these events deviate from Einstein's predictions.

"The recent detection appears to be the farthest yet, with the black holes located about three billion light-years away," said Bose, professor and researcher in the Department of Physics and Astronomy. "Data from the discoveries are helping us explore the history of our universe in ways that were not possible before."

How do binary black holes form?

LIGO's latest findings provide clues about the directions in which the black holes were spinning before they collided. As pairs of black holes spiral together, heading towards a collision, they also spin on their own axes—like a pair of figure skaters spinning individually while also circling around each other.

The LIGO team's analysis suggests these spins were misaligned, indicating that the pair of black holes might not always have been together in a tight binary system but, rather, randomly came together over time.

"While our findings are not conclusive, they suggest that binary black holes aren't always born together," Bose said. "In a fraction of cases, they may be born from stars in very different parts of a galaxy or star cluster then come together later in life."

WSU's contribution

Scientists at WSU collaborated with members of the LIGO Scientific Collaboration to distinguish gravitational wave signals from noise artifacts. They contributed to the work of canceling out the other myriad noises picked up by the twin LIGO detectors in Hanford, Wash., and Livingston, La., that weren't gravitational waves.

LIGO's detectors are designed to register the slightest of vibrations — 1/10,000th the diameter of a proton — caused by signals from space. But the devices also detect other disturbances triggered by such earthly events as trucks on a highway, earthquakes, explosions, lightning strikes and even waves crashing on the shore hundreds of miles away.

Bose, Mazumder and Hall worked with other LIGO scientists to identify the frequencies of these disturbances. Akin to a giant set of noise-canceling headphones, their work helped researchers home in on deep space signals while blocking out everything else.

“Since 2015, we have worked hard with our colleagues to improve the sensitivity of the LIGO Detectors. A false alarm, where LIGO mistakes a signal from a non- astrophysical source like an earthquake or lightning strike as a gravitational wave, is only likely to occur once every 70,000 years,” Bose said. “LIGO's increased sensitivity is helping to extend the depth to which we can search for these cosmic events.”

Boosting location capabilities

Finding the exact location of the source of gravitational waves deep in space is challenging work. LIGO scientists were able to identify the wide patch of sky where the black hole merger took place but were unable to pinpoint its exact location.

Bose is helping to develop a third LIGO detector in India that will provide the triangulation necessary to more precisely locate gravitational wave-producing objects in space. The new facility is expected to be operational by 2024.

The first two detections of gravitational waves generated by the collision of two black holes were reported last year. They marked the end of a decades-long, multimillion dollar quest to find them and confirmed a major prediction of Albert Einstein's 1915 general theory of relativity.

The LIGO Scientific Collaboration (LSC) is funded by the National Science Foundation and led by the California and Massachusetts Institutes of Technology. The LSC and the Virgo Collaboration in Europe made this discovery, and together consist of more than 1,000 scientists from around the world.



LIGO Laboratory operates phototwo detector sites, one near Hanford, Wash., and another near Livingston, La. This shows the Hanford detector site.

WSU PHYSICISTS HAVE CREATED A FLUID THAT BEHAVES AS IF IT HAS NEGATIVE MASS

By Eric Sorensen, WSU Science Writer

Washington State University physicists have created a fluid with negative mass, which is exactly what it sounds like. Push it, and unlike every physical object in the world we know, it doesn't accelerate in the direction it was pushed. It accelerates backwards.

The phenomenon is rarely created in laboratory conditions and can be used to explore some of the more challenging concepts of the cosmos, said Michael Forbes, a WSU assistant professor of physics and astronomy and an affiliate assistant professor at the University of Washington. The research appears today in the journal *Physical Review Letters*, where it is featured as an "Editor's Suggestion."

Hypothetically, matter can have negative mass in the same sense that an electric charge can be either negative or positive. People rarely think in these terms, and our everyday world sees only the positive aspects of Isaac Newton's Second Law of Motion, in which a force is equal to the mass of an object times its acceleration, or $F=ma$.



Dr. Michael Forbes, Assistant Professor

In other words, if you push an object, it will accelerate in the direction you're pushing it. Mass will accelerate in the direction of the force.

"That's what most things that we're used to do," said Forbes, hinting at the bizarreness to come. "With negative mass, if you push something, it accelerates toward you."

Conditions for negative mass

He and his colleagues created the conditions for negative mass by cooling rubidium atoms to just a hair above absolute zero, creating what is known as a Bose-Einstein condensate. In this state, predicted by Satyendra Nath Bose and Albert Einstein, particles move extremely slowly and, following the principles of quantum mechanics, behave like waves. They also synchronize and move in unison as what is known as a superfluid, which flows without losing energy.

Led by Peter Engels, WSU professor of physics and astronomy, researchers on the sixth floor of Webster Hall created these conditions by using lasers to slow the particles, making them colder, and allowing hot, high energy particles to escape like steam, cooling the material further.

The lasers trapped the atoms as if they were in a bowl measuring less than a hundred microns across. At this point, the rubidium superfluid has regular mass. Breaking the bowl will allow the rubidium to rush out, expanding as the rubidium in the center pushes outward.

To create negative mass, the researchers applied a second set of lasers that kicked the atoms back and forth and changed the way they spin. Now when the rubidium rushes out fast enough, it behaves as if it has negative mass.

“Once you push, it accelerates backwards,” said Forbes, who acted as a theorist analyzing the system. “It looks like the rubidium hits an invisible wall.”

Avoiding underlying defects

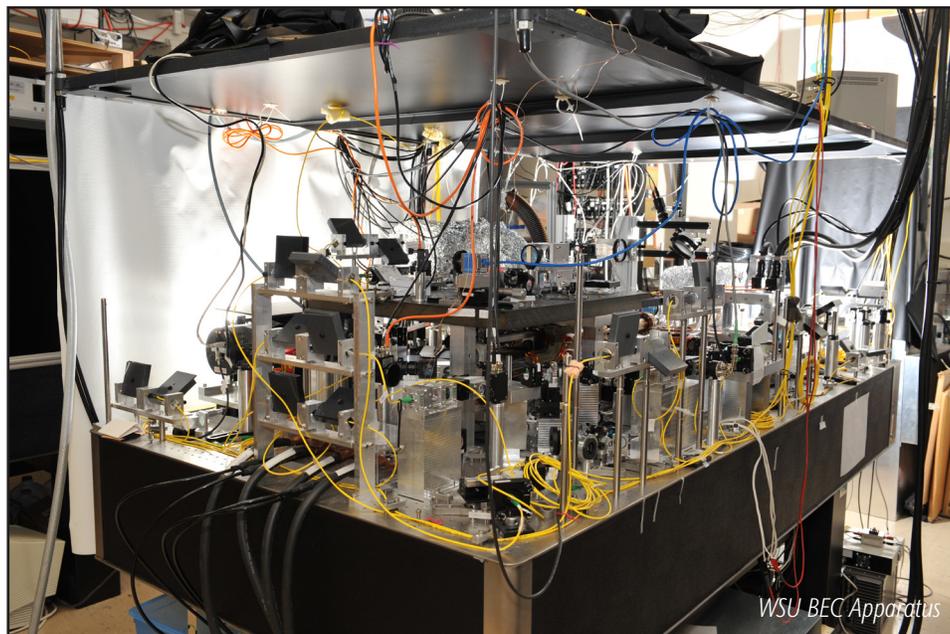
The technique used by the WSU researchers avoids some of the underlying defects encountered in previous attempts to understand negative mass.

“What’s a first here is the exquisite control we have over the nature of this negative mass, without any other complications” said Forbes. Their research clarifies, in terms of negative mass, similar behavior seen in other systems.

This heightened control gives researchers a new tool to engineer experiments to study analogous physics in astrophysics, like neutron stars, and cosmological phenomena like black holes and dark energy, where experiments are impossible.

“It provides another environment to study a fundamental phenomenon that is very peculiar,” Forbes said.

Forbes’ colleagues on the Physical Review Letters paper include WSU research assistants Mohammad Khomehchi, Khalid Hossain and Maren Mossman, as well as Thomas Busch in Japan and Yongping Zhang in China and Japan. The work was supported in part by a WSU New Faculty Seed Grant and the National Science Foundation.



ULTRACOLD ATOMS IN SPACE

FROM THE LAB OF PROF. PETER ENGELS



Photo credit: Sean Mossman

WSU takes part in creating the coldest matter in the universe onboard the ISS

In the early morning hours of May 21st, 2018, scientists and engineers gathered at Wallops Flight Facility in West Virginia to witness the launch of Orbital's OTK OA-9 Cygnus spacecraft. In Pullman, WA, three physicists anxiously waited for the countdown to launch. This was a moment six years in the making. Together with engineers from the Jet Propulsion Laboratory (JPL) in Pasadena, scientists from across the US, including members of the Engels group from WSU Physics and Astronomy, have worked to plan microgravity experiments that will challenge the concept of "cold." The Cold Atom Laboratory (CAL) is an instrument designed to cool clouds of atoms down to temperatures 100 trillionths of a degree above absolute zero (-457.67°F). CAL is a user facility, which means that it will be used by more than one set of researchers. One user group involved is WSU's own Prof. Peter Engels and graduate student Maren Mossman, in collaboration with researchers from CU Boulder and NIST (Nobel Laureate Prof. Eric Cornell, late Prof. Deborah Jin, and Dr. Jose D'Incao). They plan to perform experiments in microgravity that push forward current knowledge of how few bodies interact under the application of magnetic fields. The experiments planned by the WSU-CU Boulder team were recently highlighted in Nature News as well as other space news outlets.



Engineers loading the CAL apparatus onto the Cygnus main cargo hold. Photo credit: NASA (coldatomlab.jpl.nasa.gov).

After a successful launch, it took 3 days for the Cygnus spacecraft to catch up to the ISS for docking. The night this was to take place, the space station was visible passing over the Washington night sky. Traveling just behind the bright reflection of the space station was the Cygnus spacecraft. A few hours later, using a robotic arm, astronauts successfully grabbed hold of and docked the spacecraft. CAL has since been installed on the ISS. Keep your eyes out for some very exciting news from NASA's JPL about this cool project!

See *Nature* 557, 151-152 (2018) <https://www.nature.com/articles/d41586-018-05111-2>

FALL 2018 EVENTS

14TH ANNUAL DAD'S WEEKEND PUMPKIN DROP

**Saturday, November 3
Webster Mall**

Join us on Dad's Weekend for a smashing good time at the 14th Annual Pumpkin Drop. Sponsored by the Physics and Astronomy Club, this pre-game, gravity-bound extravaganza celebrates the fun side of science by dropping pumpkins of all shapes and sizes from the highest point in Pullman: the 12th floor of Webster Hall. Additional entertainment for kids of all ages will be on site as well.

Time of the events to be determined based on football schedule.



Physics & Astronomy Distinguished Colloquium Series

Fall 2018



October 4, 2018

Christoph Boehme
University of Utah

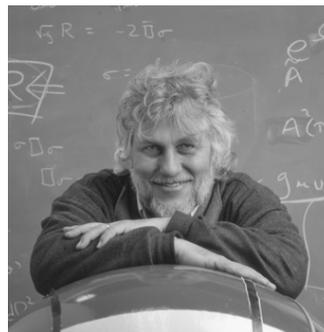
*Spin physics in small ensembles;
spin-dependent electronic transport*



October 25, 2018*

Ronald Walsworth
Harvard University

*Quantum sensing and control;
exoplanet detection*



November 8, 2018

William Unruh
University of British Columbia

*Gravity, Cosmology, Quantum
Coherence, and Music*

All events begin at 4:10 pm

Meet the speaker!
A reception will follow each lecture

Learn more at physics.wsu.edu/events/colloquium

***Additional Public Lecture on October 26 @ 6 pm**



Physics and Astronomy
PO Box 642814
Pullman, WA 99164-2814

Nonprofit
Organization
U.S. Postage
PAID
Pullman, WA
Permit No. 1

The Department of Physics & Astronomy is committed to excellence in education. We have several endowed scholarship accounts as well as an Excellence Fund that supports visiting speakers, travel and scholarship opportunities for students, provides funding for student research opportunities, and other activities that help to enrich the educational experience overall.

Gifts of any size help to support our outstanding graduate and undergraduate students and the department as a whole.

To give online, visit: physics.wsu.edu/give

Thank you!



Find us on
Facebook

[@WSUPhysicsandAstronomy](https://www.facebook.com/WSUPhysicsandAstronomy)

