DIVISION OF

Mathematical and Physical Sciences

ASTRONOMY | EARTH & PLANETARY SCIENCE | MATHEMATICS | PHYSICS | STATISTICS

Berkeley College of Letters & Science

Letter from Dean Frances Hellman

Dear Friend,

IT FEELS LIKE WE'VE CROSSED the threshold into a new era here at Berkeley. We have spent the last couple of years grappling with a variety of difficult issues, but through the leadership of Chancellor Carol Christ, we find ourselves with lean but balanced budgets, more amazing students to educate than ever, and the will to envision a great future. I'm delighted to share with you a few aspects of this vision from my vantage point as dean.

As campus has charted its strategic plan and identified its most transformative ideas, the Division of Mathematical & Physical Sciences has done the same. It's clear to me that we must reaffirm our commitment to be the best place in the world for teaching and research, for imparting and creating new knowledge. Berkeley's departments of Astronomy, Earth & Planetary Science, Mathematics, Physics and Statistics have all helped define Berkeley as one of the greatest research institutions in the world. Still, there's no time to rest on our laurels; we must adapt to the demands of our students and the trends in research. Only then can we innovate and remain on top.

We are always exploring and often leading frontier research initiatives. These are areas that map well to Berkeley's existing strengths and dovetail with student interests. Looking out at the next decade, we see exciting opportunities in areas such as gravitational waves, a new lens with which to view the Universe; fundamental climate research and sustainable materials for a healthier planet; planetary science with specific interests in Mars and in exoplanets; new, more sensitive approaches to understanding dark matter and dark energy; quantum information science and quantum materials. And underpinning just about every research track is the data science and mathematics that helps us make giant leaps.

One issue, that I like to say is a wonderful problem to have, is the huge increase in STEM majors. Math, for example, has more majors than ever (over 1,000) and teaches about 20,000 student credit hours a year. For this reason, we are creating assessment tools to help departments better place and educate our students. We also need to look at how we best provide core courses to students, teach them effectively, provide relevant material, offer valuable research experiences and improve teaching through state-of-the art labs, well-funded field courses, and 21st century classrooms. As a complement to the teaching, we view the creation of mentoring and undergraduate research programs, both of which provide support structures to all students and plug holes in the leaky pipeline, as a top priority.

Our faculty are the heart of discovery and teaching. We work hard to keep the ranks strong and to recruit exciting new hires — including Bethanie Edwards (EPS), Na Ji (Physics) and Fernando Perez (Statistics) whom you'll read about in this newsletter. I take great pride in the number of faculty we've retained over the last year, despite the deep pockets of our peers. I like to think that they stay at Berkeley because they feel independent and supported; creative and grounded in a shared mission.

One place we hope to see improvement in the coming years is in creating greater diversity among our faculty and students. You'll read about a successful Berkeley program — the California Alliance — that is doing amazing work in that regard (with national implications), and you'll hear more in the coming year about our special initiatives.

And then there's you, our loyal and generous supporters who partner with us on this journey of discovery and learning. I'm tremendously grateful for the support you show our mission, your engagement and loyalty. There will be many new opportunities to seize, and I look forward to exploring them together.

With Gratitude,

Frances Hellman

P.S. We would like to thank our contributing writers from the Berkeley Science Review. To learn more about this graduate student publication, visit berkeleysciencereview.com.

PHYSICS

LIGO in the Hellman Lab

By Miguel Zumalacarregui, Berkeley Science Review
Marie Curie Global Fellow at the Berkeley Center for Cosmological Physics

THE DETECTION OF gravitational waves (GWs) was an immense technological challenge that took a century and the effort of thousands of scientists. They were first predicted in 1916 by Albert Einstein and detected in 2015 by the Laser Interferometer Gravitational-Wave Observatory (LIGO), a detection that won UC Berkeley alumnus Dr. Barry Barish, among others, the Nobel Prize in 2017. The detected GW signals modify the distances travelled by the LIGO lasers' light, by one part in 1021, corresponding to less than the size of a proton in the 4km arm of the detector. In other words, recording a gravitational wave requires measuring distances with a precision akin to the diameter of a hair relative to the distance between the Earth and the Sun, by far the most precise length measurement ever made. Many sources of noise and potential error had to be taken into account and mitigated for this detection to be possible.

Frances Hellman joined LIGO's Center for Coatings Research a year ago to develop new materials that may improve the sensitivity of GW detectors. The precision of LIGO in its central range of frequencies is limited by the properties of the mirrors that reflect the laser. Professor Hellman is exploring how new mirror coatings may improve the sensitivity of the detector, in particular, by reducing the background noise produced by the amorphous (non-crystalline) materials used for these coatings. Ultimately, she hopes to improve the measurement of black hole and neutron star mergers for upcoming LIGO upgrades and next-generation GW detectors.

The initial motivation for Hellman's work was to better understand amorphous solids, materials whose properties are connected to fundamental problems in condensed matter physics. In the quest to understand these open questions, Frances experimented with vapor deposition, a technique that she uses to produce a near-ideal glass, which reduces background noise and thereby improves GW detection. Her work is a prime example of how fundamental research may find innovative and unexpected applications.

GRADUATE STUDENT HILARY JACKS AT WORK IN THE HELLMAN LAB. Photo: Sarah Wittmer

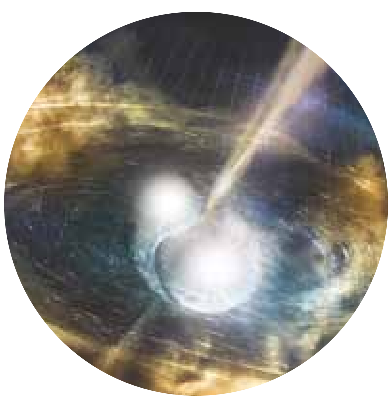
Let There Be Light: New Ways to See Gravitational Waves

By Miguel Zumalacarregui, Berkeley Science Review
Marie Curie Global Fellow at the Berkeley Center for Cosmological Physics

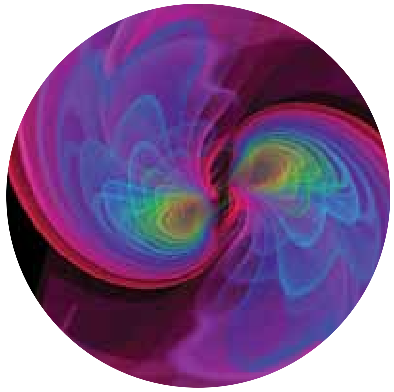
IN 1862, barely six years before UC Berkeley was founded, it was understood that the light colors we see are just special instances of electromagnetic radiation, encompassing other phenomena (radio-waves, microwaves, gamma rays or x-rays) that cannot be sensed by the human eye. In the 20th century, these forms of electromagnetic radiation have provided new visions of the cosmos.

The detection of gravitational waves (GWs) has bestowed us with a new means to perceive the universe. GWs are fluctuations in the fabric of space-time that cause minute distortions of physical distances as they travel. Because gravity is immensely weak, only very compact objects in the most extreme situations emit a strong enough signal to be detected. The first GW detections were produced by a pair of black holes in close orbit as they merged to form one larger black hole. Both objects were several dozen times heavier than our own Sun, but only tens of kilometers in diameter.

Astronomy Professor Chung-Pei Ma is searching for the largest black holes in the Universe, each one billions of times heavier than the Sun. These monsters inhabit the centers of galaxies, and would produce noticeable GW signals if two galaxies that contain them collide.



ARTIST'S ILLUSTRATION OF A BINARY NEUTRON STAR MERGER:
Credit: NSF LIGO Sonoma State University

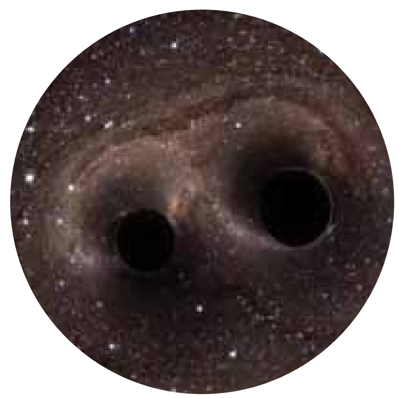


GRAVITATIONAL WAVES COMING FROM INSPIRALING MASSIVE OBJECTS:
Credit:Ossokine, Buonanno and Berger

However, these objects are too large for their signals to be detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO), therefore other techniques are necessary. Professor Ma is researching how to detect GW systems using pulsars, rapidly rotating neutron stars that periodically emit energy. The regularity of pulsar emissions allows researchers to use them as cosmic beacons and measure their distortion caused by passing GWs, similar to LIGO's laser system but separated by astronomical distances.

Neutron star collisions also produce a GW event, first observed in 2017 by the LIGO and Virgo detectors. Neutron stars are as dense as an atomic nucleus, yet not quite dense enough to form a black hole. Neutron stars rip each other apart when their orbits are very close, ejecting some of their material into space. This unstable nuclear material, free from the gravity of the star, quickly starts undergoing nuclear reactions and forming new heavy elements. This process, known as a kilonova, was first observed after the detection of GWs and gamma-rays from a neutron star merger.

Members of the Berkeley Astronomy and Physics Departments have made essential contributions to interpreting these observations. Professors Daniel Kasen and Eliot Quataert, together with (then students) Jennifer Barnes and Bryan Metzger, were the first to predict in detail what a kilonova would look like. Their theoretical studies used relativistic simulations, nuclear physics and atomic models to determine how nuclear matter would be ejected, decay and glow. The first observed kilonova confirmed their predictions for the formation of heavy elements, made years before the event was observed. In a very unusual case for astronomy, an area of science in which theory struggles to keep up with data, their predictions were key to confirming that neutron star mergers are the fundamental mechanism to produce heavy elements, including gold.



COMPUTER SIMULATIONS OF A BLACK HOLE BINARY SYSTEM:
Credit: Black Holes Xtreme SpaceTimes Project

GW detections are already reshaping our understanding of the universe, and we can only imagine where they will take us. Just as with GWs, the theory of electromagnetism started as a purely intellectual endeavor. However, both gradually became the basis for technological and economic prosperity. As we celebrate the 150th anniversary of the University of California, it is worthwhile to reflect on the value of basic science and its far-reaching potential.

A Scientist Comes Home

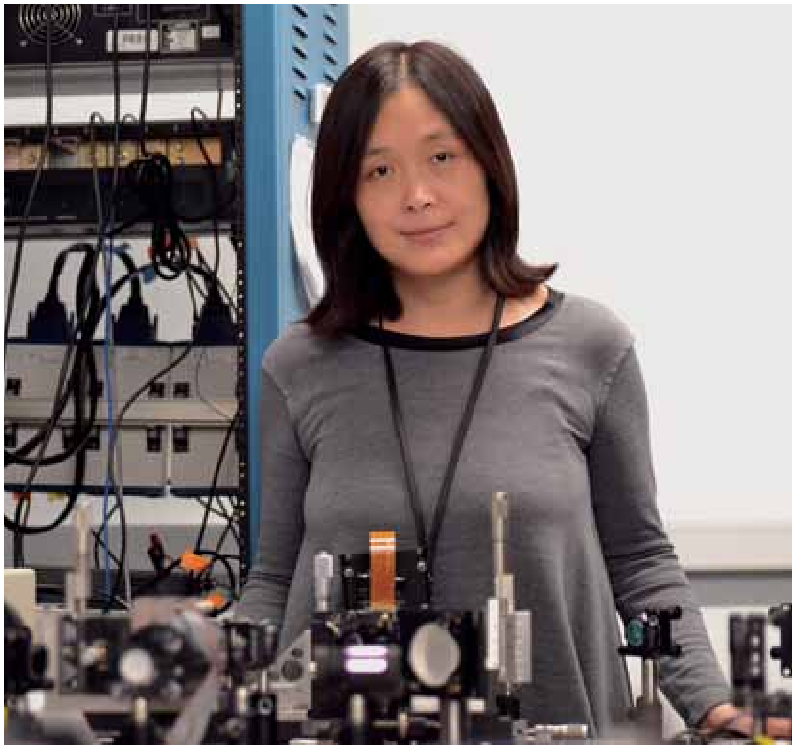
ASTRONOMERS STRUGGLE with starlight that gets distorted during its journey through the atmosphere — resulting in the "twinkle" immortalized in the nursery rhyme. By adjusting the shape of telescope mirrors to compensate for this aberration — a technique called adaptive optics — star gazers can create a clearer cosmic image.

Biologists face a similar problem when they peer inside the body to observe how it works microscopically. Opaque tissues scatter light in obstructing ways, like trying to see a star stuck behind a cloud. Light microscopy remains the best technology for resolving the smallest elements in the brain, for instance, but the deeper one delves the fuzzier the view. As Na Ji puts it, "You cannot see through the brain. It looks like tofu."

Fortunately, Ji has the biologists' backs. The Luis Alvarez Memorial Chair in Experimental Physics and a new associate professor in the Departments of Physics and Molecular & Cell Biology, she is an expert at applying tools from physics to solve problems in biology. Such as, how can you make images of brain neurons and synapses more deeply, crisply, and quickly?

For more than a decade, Ji has been developing a method derived from adaptive optics called indirect wavefront sensing for use with two-photon fluorescence microscopes. This method measures how a specific specimen is distorting light, and then obtains optimal focus by manipulating individual light waves to direct their peaks to the same point of interest at the same time.

Ji's Berkeley lab, which includes a team that's half physicists and half biologists, conducts experiments with the image-processing pathway in the mouse brain. One goal of these experiments is to demonstrate for other labs that adopting adaptive optical technology improves image quality and enables discovery. For instance, one recent study successfully imaged transmissions through the ultra-thin filaments called axons that run deep in the brain from the thalamus to the primary visual cortex. The images revealed a surprising result concerning the nature of neural circuit input that would not have been detected without access to the sharper resolution. Says Ji, "To image within small structures like synapses, in vivo, you need adaptive optics."



NA JI IN HER BERKELEY LAB Photo: Sarah Wittmer

Ji partly credits China's rigid college-entrance exam for her comfort with crossing disciplinary boundaries. She intended to study biology in college, but her exam result diverted Ji to her second choice, chemical physics. Then, when she came to Berkeley for doctoral studies in chemistry, she ended up in the lab of physicist Yuen-Ron Shen, who encouraged students to explore a range of fields and think from different perspectives. It all proved useful training to someone who simply aims to understand the natural world — especially the intricacies inside the human brain. Recently, Ji and her husband, Nobel laureate Eric Betzig, have combined forces to unite adaptive optics with Betzig's focus, super-resolution microscopy, in order to generate optimal images inside a living brain.

"I'm a neurobiologist wanna-be," says Ji. "Instead of being limited to a single subject, I feel like my educational background allows me to understand many things. So, I just consider myself a scientist."

Jupyter Rising

FERNANDO PÉREZ AND BRIAN GRANGER Photo: Adriana Restrepo

PROCRASTINATION SOMETIMES SPARKS a revolution. In 2001, Fernando Pérez was pursuing a Ph.D. in physics at the University of Colorado, studying quarks and gluons. Frustrated by having to analyze the output of supercomputer simulations with "a rickety Rube Goldberg machine of many programming languages and tools," he decided to build something simpler.

Pérez sought an interactive environment in which he could run code, plot data, and analyze results. He thought, what better way to delay a dissertation than to get sucked into programming? An office mate's tip led Pérez to the Python programming language. He learned of and contacted two other scientists who had begun building interactive tools in Python. Too busy to collaborate, they shared some code with Pérez, who submerged into a coding binge. Weeks later, he resurfaced with the first iteration of Interactive Python, or IPython: an open platform and unified environment for exploratory scientific computing.

Fast forward some 15 years. Pérez, who did eventually complete his dissertation, is an assistant professor of statistics at Berkeley, a senior fellow with the Berkeley Institute for Data Science, and a faculty scientist at Lawrence Berkeley National Laboratory. He co-leads an international team of collaborators who have expanded the IPython platform to play not just with Python but with C++, R, Julia, and many more languages. The effort has a new name, Project Jupyter.

Think of Jupyter as a platform for interactive, human-centered computing and team-based science. Or, in Pérez's words, "Jupyter is a gateway to an entire ecosystem of open-source tools." Jupyter's protocol enables all the parts to communicate with each other — and with people. Its interface has been designed so that collaborators can see and share code, data, and visualizations as reproducible "computational narratives," all accessed through a web browser.

"The human at the helm is what matters," says Pérez. "It's all about building machinery to interface between computational resources — whether it's a supercomputer, a laptop, the cloud — and your thinking about a problem."

Jupyter has quickly become the go-to tool for data analysis in research, education, and industry. In June, several Jupyter team members accepted the Association of Computing Machinery's 2017 Software System Award and a $35,000 prize for developing software with a lasting influence. For example, Jupyter will be used by astronomers at the Large Synoptic Survey Telescope (LSST) in Chile, to analyze the terabytes of data it will generate each night as it surveys the southern skies. The telescope will come online in 2022.

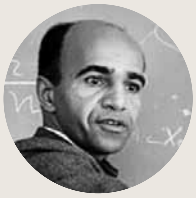
Reaching this point required a dedicated, talented team of about two dozen consistent contributors. Pérez's co-principal investigator is physicist Brian Granger of Cal Poly San Luis Obispo, and several past and present Berkeley students have also had integral roles. Early funding for the project came from private sources (the Sloan and Moore foundations and the Helmsley Trust), but the tech industry and government agencies have since gotten interested.

Spinoff projects have begun taking Jupyter into new orbits. JupyterLab is in beta release as the next-generation user interface that's more flexible, modular, and extensible. This should encourage use by new scientific communities. Early adopters of Jupyter include facilities running supercomputers, electron lasers, genomic sequencers, and a deep-survey telescope. Another spinoff, named Binder, packages Jupyter-based scientific analysis into a sharable, reproducible unit — reimagining the processes of peer review and research publication.

On November 1st, a new interdisciplinary division, provisionally named the Division of Data Science and Information, was announced. The Mathematical & Physical Sciences Division has played a key role in the creation of this division, particularly the Statistics Department and the Berkeley Institute for Data Science (BIDS), but also many other departments, such as physics and astronomy, who use data science to revolutionize how we look at the Universe. The Division of Mathematical & Physical Sciences and all of its departments are excited to partner with this new division.

DAVID BLACKWELL HALL

Newest Freshman Housing Honors Renowned Statistician



The opening this fall of the campus's newest residence hall recognizes David Blackwell — the first tenured African American professor at Berkeley and the first African American mathematician elected to the National Academy of Sciences. The first new campus dorm since 2012, David Blackwell Hall is a LEED Gold-certified building located a block from Sproul Plaza that will house some 700 freshmen and other students. The complex includes social and study areas on each floor.

Chancellor Carol Christ, who selected Blackwell's name for the building, called him an "exemplar of what Berkeley stands for: scholarly excellence of the highest caliber tied to a mission of social justice and inclusion." Recruited to Berkeley in 1954, Blackwell soon joined the new Department of Statistics. He served 34 years on the faculty.

With a knack for making theoretical contributions in diverse research areas, Blackwell became a leading expert in game theory. He helped develop the Rao-Blackwell Theorem and the statistical method of dynamic programming. Blackwell died in 2010 at age 91 and posthumously received the National Medal of Science four years later.

Blackwell did not always love math. He recalled, "I could do it, and I could see that it was useful, but it wasn't really exciting." At age 16, he entered the University of Illinois at Urbana-Champaign — emerging six years later with his Ph.D. in mathematics. By then, Blackwell had discovered the elegance of mathematics and realized that, "The whole subject was just beautiful." He shared this belief throughout his career with undergraduates and colleagues alike.

The Next Generation of Oceanography

By Hayley McCausland, Berkeley Science Review
Graduate student in Molecular & Cell Biology

RESEARCHERS RECOVER A SURFACE-TETHERED NET TRAP — A DEVICE USED TO COLLECT SINKING PARTICLES AND CELLS FROM THE OCEAN — IN THE SARGASSO SEA OFF THE COAST OF BERMUDA. Photo: Sunita Shah Walter

ASSISTANT PROFESSOR BETHANIE EDWARDS, the newest addition to the Earth & Planetary Science faculty, brings with her to Berkeley fascinating insights into the dynamics between the atmosphere and the ocean, as well as innovative new ways to study them. "Fifty percent of the carbon we put out into the atmosphere gets taken up by the ocean," she explains. In the modern industrial age, when humans dictate much of the carbon cycle due to our vast amount of emissions, Professor Edward's research on how microbes behave in the ocean provides an important look at the current state of Earth's carbon cycle, and how it has been altered by climate change.

One group of photosynthetic organisms that Dr. Edwards studies are called diatoms. These microbes soak up carbon from the atmosphere as they convert sunlight to energy. When they die and decompose, much of that carbon sinks through the layers of the ocean. Some of it is converted back into carbon dioxide as bacteria break down molecules for energy, and is released back into the atmosphere. However, the carbon that sinks "won't be in the atmosphere for about a thousand years. So that's a really important part of the carbon cycle," says Edwards.

If the diatom population experiences some type of stress — like nutrient deprivation, viral infection, or getting eaten by grazer cells — they start to break down and send chemical stress signals into the environment. Changes in the makeup of the diatom community can alter how the ecosystem functions, in terms of carbon turnover.

During her Ph.D. in chemical oceanography at Woods Hole Oceanographic Institution, Edwards studied these chemical stress signals between diatoms and other microbes using lipidomics, a pioneering method for identifying large numbers of fatty acids. Her postdoctoral research at the University of Hawaii's Center for Microbial Oceanography focused on investigating large data sets, called metagenomes, that contain genetic information for thousands of organisms. Edwards was able to identify which microbes were present in a water column over time, and based on which resources they consume, infer how they influence carbon cycling in the ocean.

At Berkeley, Edwards will combine her expertise in lipidomics and metagenomics to link the identities of microbes with the lipid readout of what's happening between members of the ecosystem. These data can also help to explain fluxes of carbon in the ocean.

In addition to her work in oceanography, Edwards is planning to use her lipidomics data to better understand how diatoms can be utilized for drug discovery and biofuel production. The information the lab collects on what lipids the diatoms produce, and which genes are required to make them, can lead to more efficient production of large amounts of many key molecules.

Berkeley is a change for Edwards, who spent much of her academic career at research institutes. She explains, "It's nice to be at a university with that collegial feel and other schools of thought that you can interact with to diversify your own ideas." She is looking forward to setting up collaborations with Jim Bishop, Professor of Earth & Planetary Science, as well as working with scientists at Lawrence Berkeley National Laboratory.

Lipidomics is a subfield of big data in biology that has been slow to take off but will be crucial in understanding Earth's oceans. As Edwards says, "It's the idea that we can go from this molecular level of understanding and extrapolate that to this bigger, biome-wide understanding of geochemical cycling." Bethanie Edwards is bringing the next generation of oceanography to Berkeley.

THE CALIFORNIA ALLIANCE: Creating Connections in STEM

THE CALIFORNIA ALLIANCE for Graduate Education and the Professoriate has a clear goal: to increase the participation of underrepresented minority postdoctoral fellows and professors at top-tier universities. In its four years of existence, the program has had huge success in working toward this aim.

UC Berkeley formed the Alliance in 2014 with three other top-notch California schools — Stanford, UCLA and Caltech — to address the seemingly intractable underrepresentation of minority postdoctoral fellows and faculty in STEM fields (science, technology, engineering and mathematics) at prestigious universities. With support from the National Science Foundation (NSF), the Alliance now recruits exceptional underrepresented graduate students and postdocs, and offers them faculty mentoring, professional development, and academic networking opportunities.

Because top-tier universities supply much of the professoriate in the United States, increasing diversity at this level will increase it in many tiers of higher education. The Alliance has grown rapidly, and its network now includes prestigious universities beyond California: Harvard, University of Michigan, Georgia Tech, UT Austin, and University of Washington.

The Alliance was based on clear evidence that STEM minority students are not adequately represented at the highest levels in academia. Studies show significant fall-off of underrepresented minorities in the sciences from the graduate level on. NSF reports indicate that 10% of new Ph.D.'s are underrepresented minorities, while only 6% go on to find postdoctoral positions, and 4% earn faculty positions.

Unfortunately, there has been a prevalent belief in higher education that few qualified underrepresented minority candidates exist in STEM fields. But the Alliance has disproved that, recruiting 37 exceptional postdoctoral fellows in four years — six times the number originally funded by NSF. That's a significant increase in those gaining access to opportunities.

"No one can claim any more that we can't find qualified minority applicants," says Alliance co-founder, University of Washington Provost (and former Executive Dean of Berkeley's College of Letters & Science) Mark Richards. "We have. They are here."

Dean Frances Hellman, who oversees the Alliance, states it plainly, "This program embodies my division's mission to diversify. The time has come for parity in all ranks of the university: faculty, postdoctoral fellows and students. The creation of the Alliance is an important step in that journey."

ASSISTANT PROFESSOR OF EARTH & PLANETARY SCIENCE BETHANIE EDWARDS WITH FORMER UCLA POSTDOC AND CURRENT GEORGIA TECH FACULTY MEMBER OMAR ASENSIO AT A CALIFORNIA ALLIANCE EVENT. Photo: Brittany Hosea-Small

How has the Alliance achieved its success? "People have spent a lot of time trying to identify what dissuades members of underrepresented groups in science from going on to faculty careers," says Colette Patt, UC Berkeley Assistant Dean, "but the Alliance doesn't focus on that. Instead, we support brilliant and accomplished minority students in STEM to achieve their goals. There's a very simple logic to it."

"What the fellowship gave me was visibility," says Marcella Gomez, a former California Alliance fellow who is now an assistant professor in applied mathematics and statistics at UC Santa Cruz. "All we're asking for is equal visibility."

"For majority individuals," says Alliance participant Amal El-Ghazaly, "finding a group to belong to can be easier, but often those groups exclude others. [For underrepresented groups], not having a support network makes the work even more challenging."

The Alliance is particularly excited about its new Research Exchange (RE) program, which allows graduate students and postdocs to visit a research group at any Alliance institution. Students identify professors and/or labs to visit, and the RE pays for travel. Visits typically last a week and help integrate Alliance participants into the broader scientific network.

Says Reginald Evans, a graduate student at the University of Michigan who recently participated in the Research Exchange, "I was able to get access to leading experts in fields I was interested in. I hope to develop and maintain these connections throughout graduate school and beyond."

Access and mentoring are key for underrepresented groups, which the Alliance's success has borne out. Former participant Ruth Herrera states, "The Alliance offered me guidance and helped me gain confidence. I was lacking role models, but the Alliance definitely provided them for me."

For more, please visit: **CALIFORNIA-ALLIANCE.ORG**

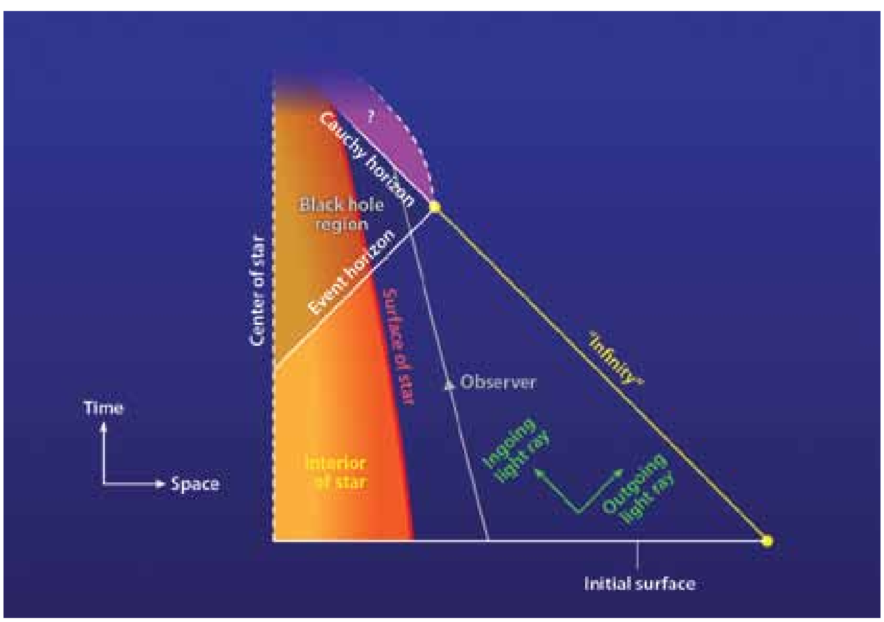
The Future of Black Holes

Photo: Allegra Boverman

SUPPOSE YOU hit a baseball with a bat. Given measurable data — point of impact, swing speed, and variables like drag coefficient and backspin — a mathematician, using the laws of gravity and the rules of determinism, can predict where the ball will land. But according to former UC Berkeley Miller Research Fellow Peter Hintz, who was hosted by mathematics professor Maciej Zworski from 2015–18, if you hit that ball deep into a particular type of black hole, all bets are off. The past — in this case, the air-splitting crack of the bat — will not determine the ball's future. Even more astounding? Should you happen to pass through a black hole yourself, you might actually survive. What might happen next is anybody's guess. Your future could be one among an infinite number of random possibilities, and your past would have no influence on where you, or the ball, would land.

Such claims have been made in the past, but physicists have invoked "strong cosmic censorship" (SCC) to explain it away. Simply put, given Einstein's theory of general relativity, you — and that bat and ball — would be obliterated upon passing through the so-called "Cauchy horizon" of a black hole, stretched thin like spaghetti until you snap. The gravitational pull of a black hole is so intense, not even light or radiation can escape it.

However, according to Hintz, whose first math-related memory in Germany was solving pretend algebraic equations when he was five years old, mathematical calculations show that for specific types of black holes, in a universe that is expanding at an accelerating rate, it is possible to survive the passage from a deterministic world into a non-deterministic black hole.



A SPACETIME DIAGRAM SHOWING A CHARGED BLACK HOLE FORMING FROM A COLLAPSING STAR. TRAVELING ACROSS THE EVENT HORIZON, AN OBSERVER WILL EVENTUALLY ENCOUNTER THE CAUCHY HORIZON, THE BOUNDARY OF THE REGION OF SPACETIME THAT CAN BE PREDICTED BY INITIAL DATA, OR "THE PAST." HINTZ AND COLLEAGUES FOUND THAT A REGION OF SPACETIME (DENOTED BY A QUESTION MARK), CANNOT BE PREDICTED FROM PAST DATA IN A UNIVERSE WITH ACCELERATING EXPANSION, LIKE OUR OWN. THIS VIOLATES THE PRINCIPLE OF STRONG COSMIC CENSORSHIP. (Image courtesy of APS/Alan Stonebraker)

"At the heart of the SCC conjecture is the idea that the physical world should evolve uniquely from a given initial configuration," says Hintz, who learned to code computers before he learned English. "For 20 years, theoreticians believed that indeed SCC holds true, and that all observers traveling far enough into a black hole would be obliterated. Our paper showed, even if only in a simplified model case, that this is not quite correct for certain classes of black holes."

For you and that ball to survive passing through the Cauchy horizon, where you either turn to angel hair pasta or pop out the other side into a prism of possible futures, one needs to aim for a non-rotating black hole with a large electrical charge. The catch? These types of black holes are nearly impossible to come by.

Assuming your aim is true, what dictates these multiple random futures? The Cauchy horizon is the spot where determinism breaks down. When you reach this threshold, the cause-and-effect evolution of spacetime is no longer uniquely determined, which means neither is your future.

"The point is that 'complete' knowledge of the universe prior to the Cauchy horizon is insufficient for predicting what happens after the horizon," says Hintz, who is now a Clay Research Fellow at MIT. As long as it happens consistently with the laws of physics, anything can happen. As he says, "You could even be hit by a random ball flying in your direction."

Hintz and his collaborators' landmark paper was published last January in the journal Physical Review Letters and has since spawned a flurry of new papers related to the topic. Miller Research Fellowships are granted to exceptional young scientists from around the world, as part of UC Berkeley's Miller Institute for Basic Research in Science.

Championing Diversity: A Family Tradition

When **Peter Skewes-Cox** ('77) read an article on UC Berkeley's 2016 University Medalist — mathematics student **Kaavya Valiveti** — something struck a nerve. Peter felt a connection to Valiveti; not only had he been a math student (a physics and applied math double major), he was also Berkeley's University Medalist the year he graduated. But it goes deeper than that. Valiveti, a supremely talented mathematician and woman of color, had struggled for acceptance in her traditionally male-dominated field. Not long after reading the article, Peter and his wife, Colleen (Anthropology '77), and their daughter, Stina Trainor (UC Irvine, '03), endowed The Skewes-Cox Trainor STEM Diversity Fund, whose purpose is to retain women and diverse groups in STEM fields.

Peter, a lawyer who became a Principal and Partner at PricewaterhouseCoopers LLP, had watched that company work hard to create diversity and inclusion among its ranks. "In industry, it's all about talent," he says, "and business people realize that talent comes in every shape and size." And yet, it wasn't an easy process. "I watched a lot of us straight white males work hard to create a more inclusive environment. We think we are making progress, but it isn't simple, or painless."

Peter had heard of the struggles to create diversity and inclusion in academia, especially in the hard sciences. The fact that the Academy was not succeeding in giving equal access to underrepresented groups was both a surprise and a frustration to him. He wanted to help. And so did his wife. "Colleen raised our kids to believe they could do whatever they wanted," says Peter of his life's partner, who passed away in June 2018. "She believed in equal opportunities for all people. So this fund completely embodies her values." These values were embedded in their daughter Stina who has channeled her passion for equality into high level positions in the U.S. government.

Both Peter and Colleen's connections to Berkeley run deep. Peter's family even reflects early academic inclusion, as his great-grandmother, Annie Cecilia Haehnlen, earned a Bachelor's of Philosophy degree at Berkeley in 1894 when female graduates were far fewer. Subsequently, Peter's grandfather, father, four uncles, his brother, and two of his sons received Berkeley degrees. On Colleen's side, her father, mother, sister, and brother are also Berkeley alumni. (Peter and Colleen's other three children graduated from UCLA, UC Irvine and UC Santa Cruz.)

In 2012, Peter and Colleen's son William graduated from Berkeley with a degree in history. At the history department graduation, a speaker asked the first generation graduates to raise their hands. Peter couldn't believe the number of hands that shot up, as well as their diversity. He was moved by the access and inclusion represented in his son's graduating class. "It was a true manifestation of Berkeley's core mission," he says. Peter, Colleen and Stina have now done their part to help. Thanks to them, there will be a greater diversity of hands, likely many of them also first generation students, shooting up in STEM graduation ceremonies in the years to come.

University of California, Berkeley
College of Letters & Science
101 Durant Hall, MC 2930
Berkeley, CA 94720-2930

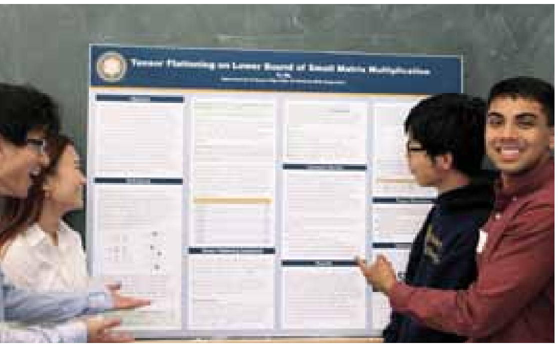
Non-Profit Org.
U.S. Postage
PAID
University of
California,
Berkeley

For more information about our program and ways to support Mathematical and Physical Sciences, contact:

Maria Hjelm
Assistant Dean of Development
510.642.5979
mhjelm@berkeley.edu

Jilliann M'Barki
Director of Development
510.643.2227
jmbarki@berkeley.edu

Meet the Math Team: Summer Undergraduate Research Fellows



THE SURF MATH TEAM: NATHAN CHEN, YU MA, JIAHAN DU AND NIKHIL SHARMA

Undergraduate students in the Mathematical & Physical Sciences Division have the unique opportunity each summer to conduct original research in their field, at a particularly early point in their scientific career. These students are mentored by world-class faculty and supported financially for their work — an important aspect of the research experience for those who would otherwise spend the summer working odd jobs to support themselves, leaving little time to delve deeper into their studies and grow as scientists.

This past summer, mathematics undergrads Nathan Cheng, Jiahan Du, Nikhil Sharma and Yu Ma were able to do just that, thanks to generous funding by mathematics alumnus David Sherrill ('83), a Senior Director at Morgan Stanley. The students submitted a proposal to participate in the Summer Undergraduate Research Fellowship (SURF) Program, a campus fellowship that supports summer research projects conducted by undergraduates under the mentorship of a UC Berkeley professor. Their proposal was selected from several applications, and they were chosen to receive Sherrill's funding to spend their summer pursuing a mathematical question.

Supervised by Professor Olga Holtz, the students formed a team, with the shared goal of improving the speed of matrix multiplication, one of the most fundamental mathematical operations. It was very much a collaborative experience, as Yu Ma explains: "We worked closely as a team daily to discuss new findings and progress, solving each other's dilemmas and inspiring new ideas." The findings that the team discussed daily throughout the summer concerned different techniques used to understand the inherent bounds on the complexity of matrix multiplications, such as border rank bounds, tensor-flattening approaches, basic transformations, and group-theoretic algorithms.

What makes this study fascinating is its potential importance in the fields of applied math and computational science. Team member Nikhil Sharma puts it best: "It was very exciting to conduct research in matrix complexity theory because it has widespread ramifications in computing. It has piqued my interest in more advanced mathematical study." Indeed, matrix multiplication is an operation that many machines, including planes, need to perform almost constantly in order to operate. Therefore, it is crucial to find fast algorithms for multiplying two matrices, and to consider what exactly the limits of these algorithms are, or how fast they can go. Jiahan Du agrees with this research principle as well, and reiterates "We used theoretical methods to tackle real-world problems with extensive applications, and the results we found were innovative and exciting."

The math team, and the entire group of SURF fellows spanning all areas of study, were able to present their findings at a conference held at the end of the summer. Perhaps most rewarding, however, was their opportunity to present their project to the donor himself. While he was visiting campus, the team met with Mr. Sherrill. They presented their work with a talk and a poster, answered his questions, and thanked him personally for the opportunity to pursue their academic goals. It also gave them a chance to share their research with a fellow mathematician. Nathan Cheng best explains the impact of the fellowship on his academic journey: "It gave me the chance to develop my skills as an independent researcher and helped me to define my interests. As I look toward graduate school and my future in general, I think I have a better idea of the kind of research I want to pursue."

UC Berkeley is the world's premier public research university, and the SURF program addresses the importance of engaging undergraduates in that research enterprise. By striving to provide all undergraduates with their own discovery experience, the program plays a fundamental role in the development of the next generation of academics and innovators. We are grateful to the many donors who make this possible.

For more, please visit: **SURF.BERKELEY.EDU**