LETTER FROM

Dean Frances Hellman

Dear Friend,

Thank you for taking a moment from your day to catch up on a few of the notable achievements in math and physical sciences at Berkeley—the tip of a very large iceberg! I hope that these stories of discovery instill in you a sense of pride and ownership because this is your university as much as it is ours. Without your support and partnership, our stories would be much less interesting and the departments I represent would not rank among the world’s very best. I’m delighted to report that in 2016, UC Berkeley is once again the world’s highest ranked public university, according to more than one reputable poll (U.S. News and World Report and Academic Ranking of World Universities, most notably). In fact, the latter ranked our physics department first in the world, with math at fourth. I’m truly proud.

You will see in these stories that our departments, professors and students continue to do incredible things. The Math Department is educating over 500 majors each year and is developing new protocols that will guide students into appropriate math classes. As a result, we believe that students will excel and stay in their chosen major; graduation rates may very well improve as well! Earth and Planetary Science is making breakthroughs in tectonics, volcanoes, and earthquakes; you’ll read about an exciting early earthquake warning system in these pages.

Statistics is playing a big role in a new campus program called the Data Science Initiative, which will have far-reaching impacts across campus and is already being implemented for our undergrads. As for Physics, unlocking the mysteries of dark matter, dark energy and neutrinos are prominent in the department, and we have exciting hires in multiple areas, most notably the hire of Nobel Laureate Eric Betzig and his wife Na Ji. Both biophysicists, they will come to campus to pursue cutting-edge research in imaging. Finally, the field of physics is undergoing the “second quantum revolution,” and Berkeley is right at the heart of it.

Astronomy, whose majors have doubled this year, has also made several new hires in star formation and exoplanets. Professor Aaron Parsons’ HERA (Hydrogen Epoch Reionization Array) project just received nearly $10 million in funding from NSF and will be a source of deep understanding of the time when the earliest stars and galaxies started to form.

We have managed challenges as well, and again, I thank you for your unwavering support. Campus has approached issues of sexual harassment head-on, and my division convened a task force of students, postdocs, staff, and faculty from our five departments to address issues and bring about change that is tailored to our community. My divisional task force is working in concert with university administrators to bring about substantive change that will be felt at every level. While the search for a new chancellor is underway, the University as well as the College of Letters & Science is strong at its core. As at any institution, leadership comes and goes, but I can assure you that our research and educational mission remains intact and, most importantly, inspired.

Gratefully,

Frances Hellman
UC BERKELEY’S ASTRONOMERS are looking far and wide for black holes in their quest to map and understand the universe. Their latest discovery, a near record-breaking supermassive black hole, lies in a galaxy named NGC 1600 in a relatively unpopulated area of the local universe, about 200 million light years from Earth in the direction of the constellation Eridanus. This discovery comes as a surprise, even to Berkeley Professor of Astronomy Chung-Pei Ma, who heads up a research initiative called the Massive Survey, tasked with finding and studying the 100 most massive early-type galaxies in the nearby universe.

The Massive Survey, funded by the National Science Foundation in 2014, is charged with weighing the stars, dark matter, and central black holes of the 100 most massive, neighboring galaxies. While the work of the Massive Survey provides better knowledge of the early universe as a whole, Ma’s team is primarily looking to understand how galaxies form and grow. Among Ma’s goals is finding the remains of luminous quasars that may be lying unsuspected in large galaxies close to Earth.

What’s the connection between black holes, quasars and galaxies? Quasars are massive and extremely remote galaxies that emit huge amounts of energy, but look like stars. Rather than being self-generating from nuclear fusion, as are stars, quasars are powered by accelerating matter as it falls towards the black holes at the centers of these active galaxies. When the universe was young, the first quasars were huge, hot and powerful. As the matter surrounding the black hole is consumed, a quasar dies, leaving behind a dormant massive black hole. Quasars live only in galaxies with supermassive black holes, and most galaxies have at least one black hole in their cores. There also appears to be a correlation between the size of a black hole and the size of the core galaxy, or bulge, which holds it.

This year, Ma’s discovery was significant for two reasons: the black hole is near-record size—equal to 17 billion suns—and it lies in a thinly populated area of the local universe. In the past, most massive black holes have been found at the other end of the universe in more populated areas. In fact, back in 2011, Ma and a UC Berkeley team discovered the most massive black hole on record—equal to 21 billion suns—in the Coma Cluster, which is in a more crowded area of the universe thought to be ripe for holding these massive holes. But with this year’s discovery, Ma says that conceptions of where supermassive black holes exist may have to change, and that a systematic search in less expected areas of the universe is now more valid than ever. She states, “The question now is, ‘Is this the tip of an iceberg?’ NGC 1600 is the first very massive black hole that lives outside a rich environment in the local universe, and could be the first example of a descendent of a very luminous quasar that also didn’t live in a privileged site.”

Ma believes that the black hole in NGC 1600 may house a dormant quasar. While further research is necessary to prove this, she says that this would be the first ancient quasar discovered in a sparsely populated region of the local universe.

In addition, NGC 1600 appears to be what astronomers call a “binary,” meaning that two galaxies likely merged, each bringing a black hole with them that also merged. Ma and her team will use the detection of gravitational waves that accompany black hole mergers, as well as the study of star patterns around the black holes, to determine such things as whether the supermassive hole is a binary.

As work on the Massive Survey continues, Ma and her collaborators hope to learn more about galaxy formation, binary galaxies, and the actual black hole population in what has heretofore been thought of as a desolate tract of the universe.

The results of this discovery were published in the April 6 issue of Nature.
“IN MY OPINION, THIS IS CUTTING-EDGE RESEARCH THAT WILL TRANSFORM SEISMOLOGY. THE STATIONS WE HAVE FOR TRADITIONAL SEISMOLOGY ARE NOT THAT DENSE, ESPECIALLY IN SOME REGIONS AROUND THE WORLD, BUT USING SMART PHONES WITH LOW-COST SENSORS WILL GIVE US A REALLY GOOD, DENSE NETWORK IN THE FUTURE.”

—UC Berkeley graduate student Qingkai Kong, who developed the algorithm at the heart of the app.

Would you like to know if an earthquake is coming? UC Berkeley is at the helm of a multi-institution effort to make that warning a reality. Earth and Planetary Science Department Chair and Professor Richard Allen, who also directs Berkeley’s Seismological Laboratory, and his team have developed a prototype earthquake early warning system called ShakeAlert. The system operates a network of seismic sensors throughout California and the Pacific Northwest to provide from five to eventually 90 seconds’ warning before a temblor strikes. ShakeAlert already proved its validity when it gave agencies five seconds’ notice in the 2014 magnitude 6.0 Napa earthquake.

UC Berkeley’s Earth and Planetary Science Department has long been a world leader in the science of earthquakes, and it is now playing a key role in safeguarding the millions who live in areas prone to earthquakes. This past year, the ShakeAlert team made great strides in securing a future path for the project. First, the Obama Administration and Congress renewed a funding commitment to push the project forward, while the Gordon and Betty Moore Foundation, USGS, and State of California remain key partners in the project. The Berkeley team will share the current federal funding with scientists at Caltech and the University of Washington.

Last February, Allen and his collaborators rolled out a free Android app called MyShake, which uses the phone’s onboard accelerometers to record local shaking any time of day or night. The information is then relayed to Berkeley’s Seismo Lab for analysis. Allen and his team plan to develop an iPhone app as well, and hope that this cellular network will provide the basis for a worldwide earthquake early warning system, which will help him and his team provide fast and accurate warnings to civilian and government agencies before a quake. Says Allen, “Currently, we have a network of 400 seismic stations in California, one of the densest in the world. Even if we get only a small fraction of the state’s 16 million mobile phones participating in our program, that would be a many-orders-of-magnitude increase in the amount of data we can gather.”

Look for updates from us and in the news as progress on this important project continues.
UC Berkeley’s 2016 University Medalist—the top honor bestowed on an undergraduate—was mathematician Kaavya Valiveti. While this young scholar is gifted and deserving of Berkeley’s highest undergraduate award, her road to mathematical research was a winding one.

After a period of insecurity in high school left her lost and without motivation, Valiveti found her true calling in the equations and theorems of linear algebra, abstract algebra, classical geometries, combinatorics, and topology. “With every step I took deeper into the realm of mathematics, and with every difficult problem I could solve, I was rebuilding my confidence and spirit, and thereby taking a step away from my anxieties,” Valiveti wrote of her time as an undergraduate in Berkeley’s math department.

Indeed, Valiveti soared during her undergraduate tenure at Berkeley. By her senior year, she’d taken graduate courses and had co-authored an acclaimed research paper on Lie algebra theory. But, not only did Valiveti have to work to overcome her own anxieties, she had to search for acceptance in the male-dominated field of mathematics. She explains, “Gender bias is big in STEM [science, technology, engineering, and math]. One problem is keeping young women in STEM once they express interest.” Valiveti cites support from Berkeley’s Professor Jenny Harrison, who actively champions women in math, along with other faculty mentors like Marc Rieffel, as pivotal to her success. Marc states, “She was working on the same level as top second-year graduate students on material close to the research frontier.”

Berkeley’s math department agrees with Valiveti that much more can be done to include women and underrepresented minorities in the math community. Last year faculty did exhaustive outreach to women graduate students, increasing this year’s incoming class of first-years tenfold. For her part, Valiveti hopes to become a role model to help female math students find the support they need to share their thoughts and participate freely in mathematical discussions and research.

In addition to academic achievement, the University Medal recognizes outstanding public service and strength of character. Valiveti has shown plenty of each during her time on campus. She volunteered in an after-school literacy program for Latino grade schoolers and has also raised money to improve an underfunded rural elementary school in India. “Increasing access to education for underprivileged children and improving it, is just as important to me as my work in mathematics,” she says.

This fall Valiveti headed off to MIT’s math department to complete her Ph.D. There, she plans to continue following the path she discovered at Berkeley, exploring her love of pure math and delving deeper into its mysteries. “So much of math is appreciating the beauty of abstract ideas that answer philosophical questions. It can reveal the greater mysteries about our universe.”
INCHING CLOSER TO THE BIG BANG

UC BERKELEY ASTROPHYSICISTS may soon be much closer to understanding what happened seconds after the Big Bang. Thanks to a nearly $40 million gift from the Simons and Heising-Simons Foundations, UC Berkeley astrophysicists led by Professor Adrian Lee, together with founding institutions UC San Diego, Princeton University and University of Pennsylvania, will establish the Simons Observatory in Chile’s Atacama Desert, a site that is high, dry and excellent for astronomy research. This visionary and potentially paradigm-shifting investment will allow the scientific team to merge existing telescopes at the site (the Atacama Cosmology Telescope and the Simons Array) and to develop technologies to create a new project—CMB-S4—with the aim of mining information from the cosmic microwave background (CMB).

The CMB is the thermal radiation left over after the reorganization of energy and matter that occurred after the Big Bang. This radiation is ubiquitous in the universe; astronomers can see that the CMB began saturating space at about 380,000 years after the Big Bang. Now the question is whether scientists can “look behind” the CMB to detect what happened in the earliest seconds of the Big Bang.

“I think we have a really good shot at getting the answer to whether or not inflation really took place.”

—SIMONS FOUNDATION FOUNDER JIM SIMONS

Project spokesperson Mark Devlin, a professor at the University of Pennsylvania and a Berkeley physics alum, states, “A key target of this observatory is the earliest moments in the history of the universe. While patterns that we see in the microwave sky are a picture of the structure of the universe 380,000 years after the Big Bang, we believe that some of these patterns were generated much earlier, by gravitational waves produced in the first moments of the universe’s expansion. By measuring how the gravitational waves affect electrons and matter 380,000 years after the Big Bang, we are observing fossils from the very, very early universe.”

The Simons Observatory will allow scientists to explore these “fossils” to see what they can tell us about the creation of the universe and, in particular, the polarization in the CMB. Scientists believe polarization was caused by “cosmic inflation,” a current and popular cosmological theory positing that an exponential expansion of space occurred in the earliest seconds of the universe and caused gravitational waves to be produced. The Simons Observatory team plans to use its new instruments to observe the “B-mode polarization” in the CMB, which it hopes will reveal the “signal of inflation,” a theory that has long been debated by astronomers and astrophysicists.

The magnitude of the Simons and Heising-Simons Foundation’s investment will allow scientists to take a giant leap forward in developing research instruments. The team will work to create optical telescopes with accuracy (in pixels) by more than an order of magnitude over what currently exists. These more powerful instruments will hopefully push researchers to a better understanding of the relationship between quantum mechanics and gravity, as well as the nature of dark matter, dark energy, and neutrino particles. Theoretical and computational astrophysicists eagerly await data from the Simons Observatory in order to begin what could be a new era in understanding the universe.
Tackling Election Fraud in the Digital Age

Anxiety about election fraud has recently peaked in today's highly charged political climate. Despite concerns and technological advances, there is currently no surefire way—digital or analog—to guarantee that election fraud does not occur. Voting electronically, without a paper trail, may make the initial count fast, but it is inherently insecure and subject to problems, from misconfiguration to equipment failures to deliberate hacking. Such problems can be completely undetectable.

In contrast, voting on paper ballots produces an audit trail that can be used to catch and correct many problems, including software problems, provided the paper trail is taken care of well (preventing “ballot-box stuffing,” lost ballots, altered ballots, etc.). Paper ballots can be tabulated quickly using optical scan equipment; then the tally can be checked against the paper ballots that voters had a chance to inspect before they cast the ballots.

One of the leading methods for auditing elections was developed at UC Berkeley by Philip Stark, associate dean of mathematical and physical sciences and professor of statistics. Recently named by Nancy Pelosi to the Board of Advisors of the US Election Assistance Commission, Philip developed an approach called “Risk Limiting Audits” (RLAs), for which he won the Chancellor’s Award for Research in the Public Interest. Risk-limiting audits reduce the chance that an incorrect election outcome will be certified. They collect evidence about the accuracy of the count by manually inspecting randomly selected ballots, stopping only if there’s convincing evidence that the election result is correct (or potentially progressing to a full hand count if the evidence isn’t convincing).

Risk Limiting Audits can be thought of as “smart” recounts that stop as soon as it’s clear that a full hand count would confirm the results. That allows officials to inspect as few ballots as possible while still providing strong statistical evidence that the outcome is correct—if it is indeed correct—and a large chance of correcting the outcome if it is wrong. This statistical guarantee has made RLAs the gold standard amongst methods for checking election outcomes, and it has been endorsed by the Presidential Commission on Election Administration and such organizations as the Election Verification Network, the League of Women Voters, Common Cause, the American Statistical Association, and Verified Voting.

Adoption of RLAs is spreading: they are required by law in Colorado starting in 2018, and three California laws require or allow RLAs in various circumstances. However, it is not known if any jurisdictions will use RLAs in the 2016 election. Instead, they are currently relying on procedures designed to prevent problems. While Stark agrees that an ounce of prevention is worth a pound of cure, he also thinks such procedures are not enough, and that elections should be ‘evidence-based’ rather than ‘procedure-based.’ That is, Stark argues that elections officials should be required to provide convincing evidence that they found the true winners. As he notes, “There’s no perfect system; all systems have failure modes. The best systems provide evidence that they’ve failed—and the means to recover from those failures.”

In the week following the 2016 election, Stark authored an opinion piece in USA Today (with Ron Rivest) asking for audits, and the Verified Voting Foundation has sent an online petition demanding RLAs.
Earth and Planetary Science grad student **Yuem Park** conducts research all over the world. Thanks to support from the Graduate Student Field Support Fund, generously created by donor Phil Berman, in summer 2015 Yuem was able to work in the Tigray region of northern Ethiopia. He and his research team set out to examine sedimentary rocks that were deposited immediately prior to and during a severe glaciation event around 717 million years ago when global temperatures fell low enough that land ice extended all the way to the equator, creating a ‘Snowball Earth.’ By combining field observations, chemical analyses of samples, and numerical models, Yuem and his team hope to better understand the conditions that resulted in such a dramatic climate event. He states, “Field work is the backbone of research in many of the earth sciences, and is a skill that must continue to play a central role in academia. I believe that the Graduate Student Field Support Fund is critical in enabling early career scientists to develop skills that allow them to operate effectively in the field, and therefore contribute meaningful fundamental datasets to their respective areas of study.”

**Miklos Racz**, who graduated with a Ph.D. in statistics in 2015, studies probability, including theoretical problems in genetics. One of his most exciting projects involves DNA storage, working to develop synthetic DNA as a high-density and durable medium for archival storage. Miklos says this fascinating endeavor may even be a reality in the reasonably near future! Thanks to support from The KAG Graduate Student Travel Fund, established by donor Kamil Grajski, Miklos was able to attend the Information Theory and Applications Workshop at UC San Diego last year. Grad students tell us that travel grants to attend professional conferences are tremendously valuable, enabling them to learn what’s happening at the cutting edge, as well as to create the professional networks that further their work.

Stars fascinate **Milo Buitrago-Casas**. A second-year student in the physics Ph.D. program who holds a master’s in astronomy, Milo studies our closest star, the sun. Thanks to support from The Friends of Warren Hellman Fund, he is currently able to conduct research that analyzes x-rays generated by explosions in the solar atmosphere. Milo and a multi-institutional team are charged with the launch of a solar x-ray telescope aboard a NASA sounding rocket, which is set to fly in summer 2018. Milo says that studying the way our sun functions will not only make more accurate space weather forecasts possible, which is crucial for the functioning of many technological devices, it will also contribute to our understanding of the behavior of other stars in the universe.