DIVISION OF

Mathematical & Physical Sciences

WINTER 2023

Berkeley College *of* Letters & Science

ASTRONOMY | EARTH & PLANETARY SCIENCE | MATHEMATICS | PHYSICS

Letter from Dean Steven Kahn

I am thrilled to be back at this unique, venerable institution after nearly three decades. It's a challenging time to assume this role, but I chose to move from Stanford to Berkeley in part because of the challenges — or opportunities — here. I was of course drawn to the enduring excellence of the research and teaching enterprise in the Division of Mathematical & Physical Sciences. My charge is to chart the course that will keep Berkeley at the forefront of the most significant science in these fields and enable us to train future generations of research leaders.

Much about the campus has changed since my time here as a graduate student and faculty member in the Department of Physics. For example, while state funding has lessened in the interim, the student body has grown much larger and more diverse.

One thing that hasn't changed is the aged infrastructure in our physical science buildings. We must plan for the eventual removal and replacement of seismically insecure Evans Hall. We need essential upgrades of research equipment and infrastructure in other buildings to keep pace with emerging, evolving avenues for discovery.

A particularly significant area of research for our division that attracts increasing interest among students is quantum information science and technology (QIST). Some 500 students a year enroll in introductory quantum mechanics courses. Quantum mechanics has been part of Berkeley's research DNA ever since J. Robert Oppenheimer began building our program in theoretical physics (see story on opposite page). This year's Nobel Prize in Physics recognized a pioneering 1972 experiment at Berkeley by John Clauser and Stuart Freedman that provided initial evidence confirming quantum entanglement, which is key to QIST. Now, Berkeley is poised to lead in the fundamental development of quantum materials, quantum computers, and quantum sensors, among other applications (see story on page 4). Creating modern lab spaces equipped for the rigors of quantum experimentation is among my highest priorities.

Another research area with renewed interest is observational astronomy. Even before this year's stunning first images and early research from the James Webb Space Telescope (see story on page 6), our undergraduate astronomy program was on the upswing — more than doubling in size over the past five years.

While growth in our faculty has not kept pace with the student body, I'm pleased to announce several recruitments to the division's departments this year. Joining us in Astronomy is Wenbin Lu; in Earth & Planetary Science, we have added Matthew Gleeson and Penelope Wieser; and in Mathematics, new faculty include: Tony Feng, Gabriel Goldberg, Michael Lindsey, Andrei Okounkov, and Yunqing Tang. In January, Raul Briceno will become a member in Physics. Welcome, all, to the Berkeley community.

Thank you, alumni and friends, for your support of Mathematical & Physical Sciences at Berkeley.

With gratitude,

Steven Kahn
Dean of Mathematical & Physical Sciences

If you need any of these materials in an alternative format, including electronic, large print or braille, please contact Melanie VandenBerghe at mevanden@berkeley.edu to make a request. Please allow 7-10 days in cases of brailled materials requests.

Cover photo: The James Webb Space Telescope's Near-Infrared Camera took this composite image of Jupiter, capturing auroras above the planet's northern and southern poles. See story on page 6. Credit: NASA, ESA, CSA, Jupiter ERS Team; image processing by Judy Schmidt.

Oppenheimer Revisits Campus

J. Robert Oppenheimer around 1930

ACCLAIMED DIRECTOR CHRISTOPHER NOLAN AND HIS CREW VISITED UC Berkeley briefly in May to film scenes for his forthcoming movie about physicist **J. Robert Oppenheimer**. Nolan has incorporated concepts from physics into previous films, such as "Interstellar," but this marks his first foray into the biopic genre.

Based on the Pulitzer Prize-winning biography *American Prometheus*, "Oppenheimer" features Cillian Murphy in the title role and Josh Hartnett as physicist colleague Ernest O. Lawrence. Hollywood luminaries Robert Downey, Jr., Emily Blunt, Matt Damon, and Rami Malek are in the cast. Shot in black-and-white on large format IMAX film, the movie will release next July.

Campus filming locations included the Campanile, of course, and the plaza outside Physics South — the building in which Oppenheimer occupied a fourth floor corner office when he arrived in 1929 as a 25-year-old assistant professor. Lawrence had joined the physics faculty the previous year, and the two developed a close collaboration, combining complementary strengths in theory and experimentation.

Having earned his Ph.D. under Max Born at the University of Göttingen, Oppenheimer was immersed in the young theory of quantum mechanics and became "a propagator of the theory which I loved." He produced influential papers foreshadowing the discovery of positrons, neutron stars, and black holes.

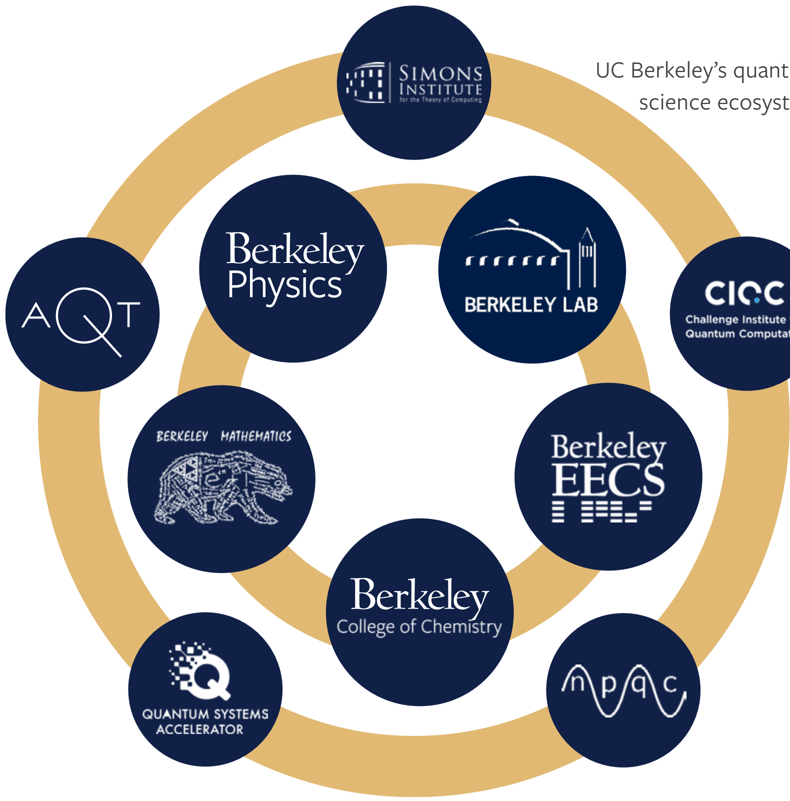
In an October 1929 letter typed on Faculty Club stationery, Oppenheimer conveyed to his younger brother, Frank, that he had little time for diversions besides horseback riding in the nearby hills, and "from time to time I take out the Chrysler, and scare one of my friends out of all sanity by wheeling corners at seventy."

A reputedly inaudible lecturer, Oppenheimer nonetheless intrigued and inspired students, who formed an entourage around the chain-smoking professor. In 14 years on Berkeley's faculty, Oppenheimer supervised 25 doctoral dissertations. He recalled, **"Starting with a single graduate student in my first year at Berkeley, we gradually began to build up what was to become the largest school in the country of graduate and postdoctoral study in theoretical physics."** That tradition continues today at the Berkeley Center for Theoretical Physics, located on the same floor as Oppenheimer's former office.

Lawrence brought Oppenheimer into a top secret research undertaking that became the Manhattan Project. In the summer of 1942, Oppenheimer convened a select group of theoreticians on campus for a month of deliberation about the feasibility of designing an atomic weapon.

The team departed Berkeley for the more secure setting of Los Alamos, New Mexico to continue the effort under Oppenheimer's scientific leadership. In October 1944, Oppenheimer wrote to Lawrence from Los Alamos: "The situation here too looks a lot better than it ever has in the past and I think we shall really get somewhere..." On the following July 16, the Trinity Test marked the first detonation of a nuclear weapon, and — paraphrasing the movie's tagline — the world forever changed.

Cillian Murphy as Oppenheimer



UC Berkeley's quantum science ecosystem

Berkeley Preparing for a Quantum Leap

THE OCTOBER ANNOUNCEMENT THAT John Clauser WAS A RECIPIENT OF THE 2022 NOBEL PRIZE IN PHYSICS signaled Berkeley's pioneering role in quantum research. Fifty years ago, Clauser was a Berkeley postdoc who collaborated with graduate student and future faculty member **Stuart Freedman** to conduct an experiment in Birge Hall. With equipment borrowed from a professor and parts rummaged around the department or built from scratch — and despite skepticism that the experiment was worth their time — the two set out to test a fundamental concept of quantum mechanics.

By measuring the polarization of paired light particles, or photons, emitted in opposite directions from calcium atoms, Freedman, who died in 2012, and Clauser concluded in a brief paper published in *Physical Review Letters*, that "we observe no evidence for a deviation from the predictions of quantum mechanics… ," while their results clearly countered the competing hidden variable theory.

This was the first experiment to provide confirming evidence for entanglement, the idea that two particles linked quantum mechanically can interact and influence each other. What happens to one particle in an entangled pair determines properties of the other, even when they are divided by physical distance. Later experiments by physicists Alain Aspect and Anton Zeilinger, who shared the Nobel Prize with Clauser, further explored and confirmed the nature of quantum interactions.

Because entangled quantum states hold the potential for new ways of storing, transferring, and processing information, entanglement is central to quantum information science and technology (QIST) and its promising — perhaps revolutionary — use in computing, sensing, cryptography, new materials, and many other applications.

The national government is investing heavily in quantum research. At Berkeley, federally funded efforts include the Challenge Institute for Quantum Computation and the Quantum Systems Accelerator, supported, respectively, by the National Science Foundation and the Department of Energy.

Led by the Division of Mathematical & Physical Sciences, in partnership with the College of Engineering, College of Chemistry, and Lawrence Berkeley National Laboratory, Berkeley is undertaking a broad research and education initiative to help establish California as a global leader in QIST. Quantum research is multi-faceted and requires close collaboration between theorists and experimentalists in the physical, computational, and other sciences. It will also require specially equipped laboratories to enable the fundamental research necessary to expand our understanding and inspire critical breakthroughs. Berkeley has a strong track record in collaborative fundamental research across the disciplines that will determine QIST's future potential.

Chancellor Carol Christ and Charles D. Brown II

"It's a very different way of creating technology," says Physics Department Chair **James Analytis**, **"We might understand the basic principles of a quantum computer, but in terms of creating something that will really answer the questions that we're trying to answer, that's still open."** For instance, researchers will need to determine the best materials for quantum computers, the most efficient and scalable method to make their information-storing "qubits," as well as develop quantum algorithms to advance discovery in various fields.

"Many of the key discoveries in the dawn of the computer era happened on this campus because of the way that people worked together," says Professor **Joel Moore**, director of the Center for Novel Pathways to Quantum Coherence in Materials. "We're now seeing the beginnings of a similar time for quantum science and technology. And I think what powers Berkeley is that this is the place where the largest number of people come into contact with the highest level of intellectual achievement."

Given the scale of its educational enterprise, Berkeley has a significant role to play in training a quantum-literate workforce that many industries foresee needing. Interest is rising among our students, as three-quarters of Mathematical & Physical Sciences majors already take a course in quantum science. And next fall, the Department of Physics plans to launch a graduate-level professional certificate program in quantum computing.

Physics Postdoc Honored

In April, Berkeley physics postdoctoral scholar **Charles D. Brown II** received the **Chancellor's Staff Award for Civic Engagement**, which recognizes exceptional individual contributions to the campus community or public good.

In his writing and presentations, Brown has shared personal experiences with anti-Blackness in the academy and promoted more inclusive representation of Black scientists at all levels. His advocacy includes being a co-founder and co-director of #BlackInPhysics. This group inspires future Black scientists by spotlighting current Black physicists and astronomers through essays, wiki-thons, and a week of social media community programming.

During his acceptance remarks, Brown said, **"...it's crucial that we ensure everyone willing and able to participate in the human cultural endeavor that is science is offered the opportunities to do so,** and to actively fight notions that science is for, or done by, a select few."

Brown's own scientific career is continuing on the physics faculty of Yale University, where he earned his Ph.D. before coming to Berkeley to work with Professor Dan Stamper-Kurn in the Ultracold Atomic Physics Group. Said Stamper-Kurn, "Berkeley should be proud that it has supported Dr. Brown as an activist Black scientist during this profound moment in history."

Cal Astronomers Earn Treasured Time on New Telescope

JWST's 21-foot-diameter, gold-plated primary mirror

AFTER A QUARTER-CENTURY IN THE MAKING, last January the James Webb Space Telescope (JWST) reached its final destination a million miles from Earth. Since summer, it has been transmitting spectacular images back to us, generating excitement for a new era of space-based astronomy. Despite delays and a budget that ballooned beyond $10 billion, Associate Professor of Astronomy **Dan Weisz** says, "[I]n terms of its discovery potential...I really think it's a great value."

Helping guide JWST from conception to completion was Senior Project Scientist **John Mather** of NASA Goddard Space Flight Center. Mather earned his Ph.D. in physics from Berkeley in 1974 and shared the 2006 Nobel Prize in Physics for his experiment detecting cosmic microwave background radiation from the birth of the universe. He says of JWST, "To get it right, we made a list of about 700 things that could go wrong" with the telescope, reassessing and testing throughout the process. **"It is up, and it does work perfectly," says Mather. "We're so thrilled."**

The return on investment for research has begun, and those benefits could continue for 20 years, until the craft runs out of fuel.

More than 100 proposals were submitted in 2017 for "Early Release Science" observing time once JWST was orbiting and operating. The Space Telescope Science Institute selected 13 proposals, including a pair of projects proposed by Berkeley astronomy faculty. "To have two of the 13 led by people at Berkeley was pretty exceptional," says **Imke de Pater**, Distinguished Professor of the Graduate School and Distinguished Professor Emerita of Astronomy. She is principal investigator on one of the chosen teams, while Weisz leads the other.

For more, please visit ASTRO.BERKELEY.EDU

Although JWST intends to open our eyes to some of the universe's dimmest and oldest objects, de Pater's team trained the telescope on big, bright Jupiter, in order to study the planet's atmosphere as well as its rings and the moons Io and Ganymede. With its 30 hours of research time, the team used each of JWST's instruments to probe Jupiter's cloud layers, polar auroras, and ring structure. The space telescope's striking images of Jupiter, including the cover of this newsletter, were released in August. "Although we have seen many of these features on Jupiter before," says de Pater, "JWST's infrared wavelengths give us a new perspective."

A self-described "advocate for tiny galaxies," Weisz received about 27 hours to study star clusters in the Milky Way and other Local Group galaxies using two of the telescope's infrared-sensitive instruments. His team's images of faint stars in the globular cluster M92, made on June 20, were JWST's initial scientific images. Other targets of Weisz's research proposal include an ultra-faint dwarf galaxy named Draco II that is poor in stars but may contain mostly dark matter, one of the major lingering mysteries of cosmology.

Other Berkeley astronomers will also earn an opportunity to observe with the largest space telescope ever. Associate Professor **Jessica Lu** will use JWST's infrared imaging capability to peer at the center of the Milky Way. She already helped to discover a supermassive black hole in the midst of our galaxy, but she's excited to search for stellar-sized "baby black holes" that may be there. Lu says, "We think there's probably a swarm of those things, so that's what we're on the hunt for with Webb."

Next November, Assistant Professor **Courtney Dressing** and graduate student Andy Mayo are in line to collect data about a curious exoplanet known as WASP-166 b. "With the James Webb Space Telescope," says Dressing, "we now have the capability to study the atmospheres of many more planets, and we have the opportunity to directly image light from other planets in more distant orbits."

WASP-166 b intrigues Dressing because it's located in a region with few known exoplanets and because this world maintains an incredibly tight orbit around the host star (six times closer than Mercury is to the sun). Blasted with intense starlight, the planet has temperatures around 1,800 degrees Fahrenheit. Analyzing how light travels through the exoplanet's atmosphere will provide information about the chemical composition, which might hold clues to how this planet formed and why it got so close to its star.

Recently, Berkeley alumni, donors, and friends gathered at the National Press Club to hear Mather, Lu, and Dressing in conversation with Dean of Mathematical & Physical Sciences **Steven Kahn**. During the event, astrophysicist Kahn recalled being part of the first National Academy of Sciences committee to recommend proceeding with JWST, which he called **"one of the more remarkable achievements of all of our lifetimes."** Given all the scientific, technical, and political obstacles that had to be overcome, the James Webb Space Telescope may end up on a list of greatest hits of human ingenuity. For now, let's marvel at the images and see what we can discover in them.

Senior Project Scientist John Mather

How Earth Keeps its Cool

MANY OF US HAVE CONCERNS ABOUT THE CHANGING CLIMATE. While sharing that concern, geologist and Associate Professor **Nick Swanson-Hysell** takes the long view in his research, pondering processes that have enabled Earth's past climate to remain stable for millions of years — as well as what triggers shifts to a radically different climate state.

"I spend a lot of time out in the field, looking at rocks, and learning what they tell us about ancient environments," says Swanson-Hysell.

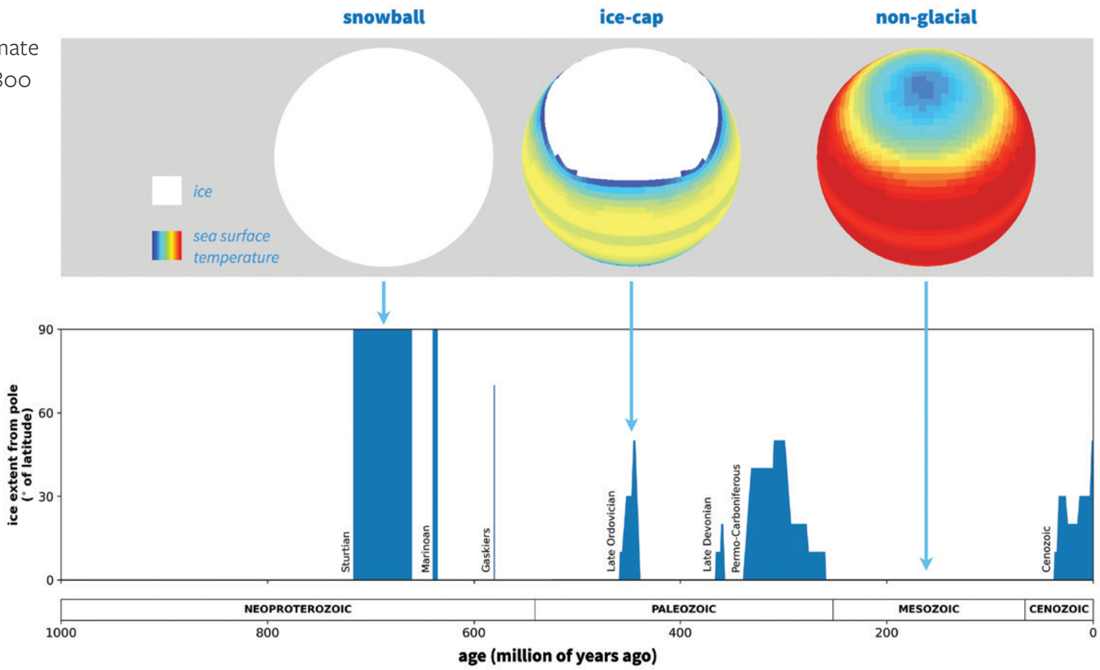
From looking at rocks as well as sophisticated paleoclimate models, he discerns three stable climate states that have recurred over the past one billion years. The current state, with finite icecaps at each pole, represents an intermediate, relatively cool climate. But global climate can veer to either of two extremes. One extreme is a "hothouse Earth" without permanent ice. This has actually been the prevailing climate for much of the last half-billion years. The other climatic extreme is a "snowball Earth," in which thick sheets of glacial ice extend from the poles to the tropics, and even to the equator. Earth was last like a giant snowball 635 million years ago.

As with current climate change, a key factor determining which climate state prevailed in the past has been the concentration of carbon dioxide in the atmosphere. Generally, cooler times coincide with less atmospheric carbon; as carbon dioxide levels rise, so do air temperatures.

Swansell-Hysell and colleagues have studied a long-term geologic process that tends to balance levels of this critical greenhouse gas. Volcanoes release carbon dioxide into the air, causing the climate to become warmer and wetter. Dissolved carbon makes resulting rainfall more acidic and better able to break down rocks into chemical components. Those weathered components wash into warm, coastal waters and are turned back into rock as calcium and carbonate combine to form limestone.

Sedimentary rocks deposited in northern Ethiopia record global change leading up to the onset of snowball Earth 717 million years ago.

Earth's three stable climate states during the past 800 million years: snowball, icecap, and non-glacial



"This is actually the way that the Earth, on a long timescale, locks up carbon," says Swanson-Hysell. "It's the long-term carbon sequestration program of the Earth."

An occasional imbalance between the source or sink of carbon, respectively, could lead to either a runaway hothouse or a runaway snowball climate. In the latter case, which has happened a few times in Earth history, as ice sheets advance toward the tropics, Earth becomes more reflective and cools down further, extending the ice to low latitudes. Imagine today's Amazon rainforest blanketed by an Antarctic-like icecap.

Field work in northern Ethiopia by Swanson-Hysell and a team that included former Berkeley graduate student Yuem Park and undergraduate Eliel Anttila, revealed rare evidence for the onset of a glacial environment in the form of oceanic rocks accompanied by volcanic ash deposits. Minerals in the ash were dated by a geochronological method to determine when the glaciers formed: around 717 million years ago. At that time, this part of Africa was located near the equator, so this study confirmed for the first time that the onset of snowball glaciation events in the tropics occurred simultaneously on multiple continents.

How does the Earth recover from a global snowball episode that covers continents in thick ice?

Swanson-Hysell says that because the rocks that could be sequestering carbon are buried beneath ice, carbon dioxide coming from volcanoes builds up in the atmosphere. Eventually, an extreme greenhouse effect melts the ice and the planet transitions to a non-glacial climate.

As for what tips the climate toward snowball Earth in the first place, Swanson-Hysell and colleagues have a hypothesis. Their paleogeographic reconstructions of the position of continents over time show that glaciation tends to spread during periods when a chain of tropical volcanic islands collides with a continental land mass. The collision and subsequent subduction removes the volcanoes as a source of outgassed carbon and causes the rise of steep mountains that include chunks of oceanic crust.

"The tropics are by far the wettest place on earth and the warmest place on earth," says Swanson-Hysell. "That means that those rocks up in the mountains can have minerals dissolve out of them much more readily." Tropical weather conditions drive weathering and erosion of these mountain rocks that release carbon back to the ocean, where it's recaptured in newly precipitated rock. While tropical mountains would typically cool the planet down to a finite icecap climate, it may be that the past configuration of continents contributed to creating a snowball Earth.

Because the changing positions of Earth's land masses and mountains hold clues to understanding long-term climate, Swanson-Hysell and his research group will work to refine paleogeographic reconstructions of continental movements, in order to better understand our planet's dynamic past and its climatic consequences.

Mathematics Department Showing Strength in Numbers

WHEN HE BEGAN HIS TENURE AS DEPARTMENT OF MATHEMATICS CHAIR IN FALL 2019, Professor **Michael Hutchings** did not anticipate what would soon ensue from the COVID-19 pandemic. "I was just learning how things worked when everything was thrown into chaos," he says. "It's very challenging to stay connected when, suddenly, everyone's over Zoom."

Despite the disruption of the past three years, Hutchings believes that the department is emerging from it stronger. For one thing, it is stronger in number. Hutchings has overseen the hiring of nine new faculty members, bringing the total to nearly 52 FTEs. Rather than recruit for new talent in specific research areas, Hutchings says, **"Our longstanding practice is that we have an open search for all areas of mathematics. It really helps us get the best candidates."**

A similarly broad-minded approach is used for hiring postdoctoral scholars as Morrey Visiting Assistant Professors, who split their time evenly between research and teaching. Using some discretionary funds to cover the research portion of salaries, Hutchings has added three additional postdoc positions. That number could grow further with philanthropic support. The young scholars, fairly fresh out of their Ph.D. programs, make invaluable additions.

Hutchings would also like to see Mathematics increase and diversify its upper division offerings beyond the core curriculum. For example, new courses could conceivably be tailored to meet the needs of either pure or applied mathematics students. "We'd really like to be able to teach more of the interesting elective courses. Having more faculty, having more teaching postdocs would certainly help with that."

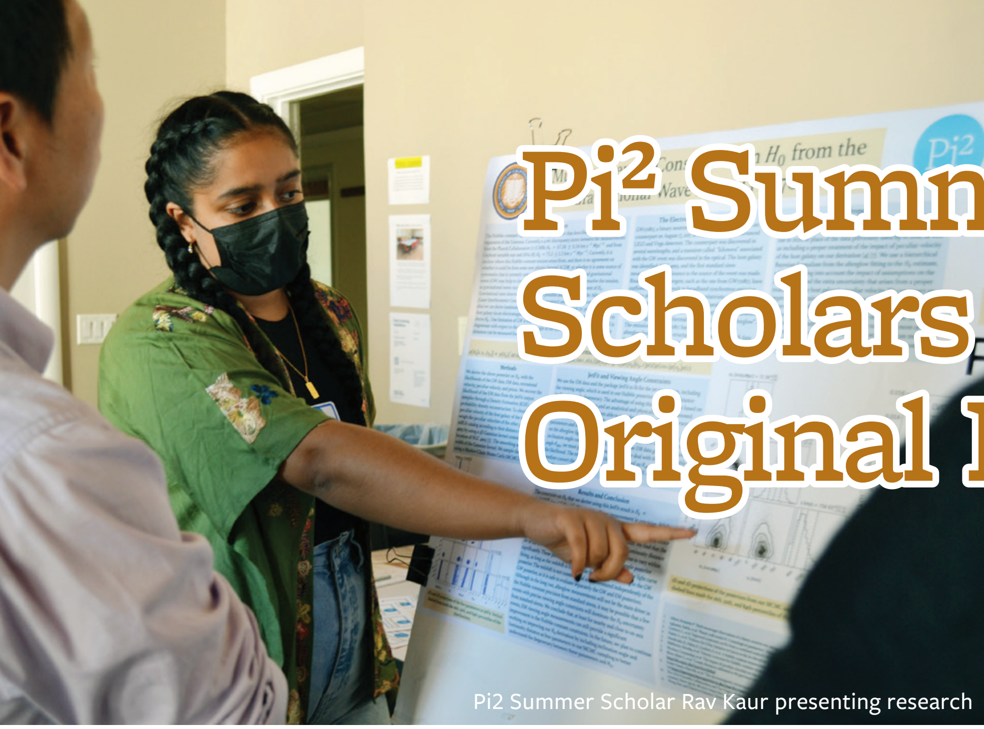
While serving as chair, Hutchings has remained active in his area of geometric research, which builds on a foundation established by Andreas Floer. A German mathematician who spent time at Berkeley as a graduate student and faculty member, Floer was appointed as assistant professor in 1988 and promoted to full professor just two years later. In 1991, he died at age 34 but left an influential legacy of research known as Floer homology.

"It's not so much a single theory," says Hutchings of Floer homology, "but a whole scheme for making theories in different contexts. There are lots of Floer theories," including a pair which Hutchings has developed: embedded contact homology and periodic Floer homology.

Last year, Hutchings and graduate student Oliver Edtmair used this theoretical framework to prove a longstanding conjecture in dynamics. The problem involves establishing the density of periodic orbits for a generic function mapping a surface, such as a sphere or torus, to itself. A periodic orbit describes the movement of a point from a starting position back to that position; for instance, a fixed point is a periodic orbit of period one, and a point that moves to another point and then returns to that first point determines a periodic orbit of period two.

Hutchings and Edtmair proved a more complicated quantitative closing lemma for periodic orbits of a type of function known as an area-preserving surface diffeomorphism. In essence, they figured out how much to perturb the function on a portion of a surface in order to create a periodic orbit. "To prove this result, I was thinking about it for a while....Oliver had a great idea to do it in a simpler and better way," Hutchings says. "Once we had the right approach, then it was pretty quick."

Pi² Summer Scholars Pursue Original Research



Pi2 Summer Scholar Rav Kaur presenting research

AS PART OF THE **Physics Innovators Initiative (Pi2) Summer Scholars Program**, eleven Berkeley undergraduates earned an opportunity over summer break to pursue original research in a faculty lab, under the guidance of a personal graduate student mentor.

The summer projects culminate in written reports by each research team and a poster presentation session that preceded the fall semester. Scanning the two rows of research posters that spanned projects in astrophysics, atomic physics, condensed matter physics, and other subfields, Physics Department Chair **James Analytis** says, "It's really great that all this was done by undergraduates."

Analytis conceived of Pi2 as an educational path that empowers students to pursue scientific careers. The initiative started by reinvigorating a pair of lower-division physics courses that serve thousands of students to include expanded experiential learning. Another aspect of the initiative is the Physics Innovation Lab, a planned maker space where undergraduates will be free to develop projects, design experiments, and realize scientific ideas.

Pi2 Summer Scholars is supported by several private donors, including physics alumnus and former IBM computer scientist **William McGee '49**. In its first two years, the program has provided 21 undergraduates with stipends of $5,500 each. The funding enables a broader range of students to participate firsthand in research, rather than find other paid work for the summer.

This year saw a marked increase in student interest about the program. Thirty students formally applied, and a committee of four graduate students, three faculty members, and one postdoc selected the cohort of scholars. Professor Feng Wang, the program's outgoing faculty lead, remarks that it's rewarding to select the scholars and then see what they accomplish with their projects. Wang's successor as faculty lead, Assistant Professor Eric Ma, served as summer mentor to physics and computer science major Jiu Chang. Together, they constructed a high-speed, lock-in amplifier with open source software as a more compact and cost-effective alternative for research.

Antonella Palmese, a postdoctoral researcher with Nobel laureate Saul Perlmutter, mentored two scholars this summer for projects in cosmology. "I love mentoring undergraduates," Palmese says. "It's great to get their energy." One of her mentees, physics major Rav Kaur, used gravitational wave data from a neutron star merger as an independent means to calculate the Hubble constant, the parameter for the rate of expansion in the universe. Emilie Cote, the second mentee, analyzed spectroscopic datasets with a machine learning model in order to identify high-energy, transient astronomical phenomena.

In addition to pursuing their individual projects, the summer scholars heard research presentations from faculty and graduate students, held a review session to discuss each other's progress, and engaged in a group hike and other social activities. Says Analytis, **"We're trying to create a community of undergraduate researchers and hope they will be part of each other's networks into the future."**

For more information about the 2022 Pi2 Summer Scholars and their projects: physics.berkeley.edu/news-events/news/20220418/2022-pi2-summer-scholar-cohort-selected

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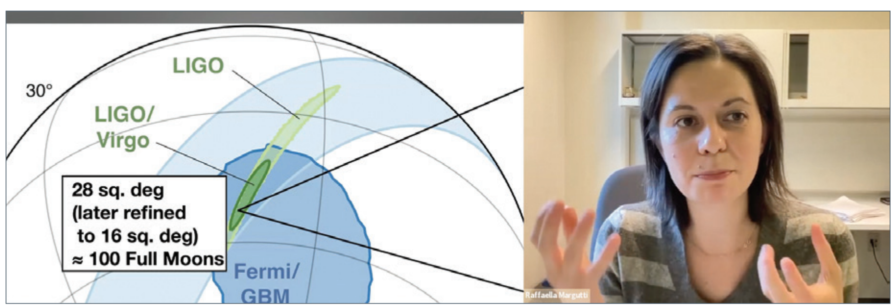
Virtual Science Lecture Series Inspires Alumni and Friends



Raffaella Margutti discusses multi-messenger astrophysics in “Gravitational Waves: Messengers from Deep Space”

Next spring will bring the sixth season of **Basic Science Lights the Way** — virtual conversations about current research that feature prominent Berkeley faculty, graduate students, and postdocs. Co-presented by the Division of Mathematical & Physical Sciences and the Division of Biological Sciences, each event packs into one hour accessible presentations about discovery-driven science, moderated discussion, and audience questions.

Reflecting Berkeley’s breadth of scientific expertise, previous topics have included: mass extinctions and ancient climatic catastrophes, black holes, the future of quantum materials, earthquakes and volcanoes, and gravitational wave astronomy. Missed any past events? You can access closed-captioned videos of each conversation or check the current schedule at **basicscience.berkeley.edu**.

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