Leading the Search for Dark Matter

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Physics is thriving at Berkeley with research milestones galore. In this issue of Berkeley Physics, you’ll get the inside scoop on a quantum materials cookbook from master chefs Professors Crommie, Lanzara, and Wang. They outline three ways to prepare a designer 2D material from atomically-thin films: stack and rotate films, regulate the population of electrons, and engineer composite excitations. They also describe their custom tools used to probe the materials’ exotic properties. These atomic pancakes may be the transistor of this generation, driving quantum technologies that promise to revolutionize computation, communication, and sensing.

Teams of researchers at Berkeley are also employing cutting-edge instruments in their quest to illuminate the vast majority of matter in the universe which is, well, … dark! For example, Professors McKinsey and Pyle look for WIMPs, which, contrary to their name, are comparatively massive. And Assistant Professor Safdi looks on the lighter side for axions, which may also hold the key to other mysteries of the universe involving gravity and quantum mechanics.

You’ll also find some of the latest research highlights from the Department, including advances in atomic-clock-based metrology and quantum computing with ternary logic. Not only can the proverbial cat be asleep and awake at the same time, it may simultaneously be in a third state where it sleepwalks.

We celebrate our alumni by sharing their stories. What they have in common is the problem-solving acumen of a physicist—a gift that allows our graduates to make a profound impact in whichever field they pursue. Berkeley Physics alum and Nobel Laureate John Mather was honored as Cal’s Alumnus of the Year for his many contributions including work on the James Webb Space Telescope, which continues to dazzle us with spectacular images of outer space. Alum Gina Quan, now a professor at San Jose State University, was active in the Compass Project while at Berkeley. She has now seeded new efforts to promote equity and inclusion in STEM fields, including spearheading studies recently commissioned by the National Science Foundation.

Please accept my well wishes for a productive year and don’t forget to stay connected! Together we can usher in the next genre of scientific excellence at Berkeley.

Irfan Siddiqi, Chair
**BERKELEY PHYSICS FACULTY ARE DRIVEN** to understand the fundamental physics of materials. Theorists hypothesize the existence of new forms of matter and behaviors, and their experimentalist colleagues develop novel materials and tools to observe these exotic properties.

“We can now control parameters to systematically study how a material goes from one quantum phase to another quantum phase,” says Berkeley Physics Professor Feng Wang, the Williams H. McAdams Chair in Physics. “Instead of solving equations in a computer, we can design model systems in our lab to test and understand the underlying mechanisms of phase formation and the properties of different phases.”

The community of condensed matter physicists researching exotic materials includes experimentalists Mike Crommie, Alessandra Lanzara, and Wang, who are physics professors at Berkeley and senior faculty scientists at Lawrence Berkeley National Lab.

Although understanding the fundamental physics is what most excites Berkeley physicists, they also expect exotic materials to lead to important applications.

“People talk about using these new materials for future quantum technology—either in quantum sensing or quantum computation—where switching is done by alternating between quantum states,” says Wang. “We’re building quantum materials by design with an unprecedented control that doesn’t exist in nature.”

In the second approach, the scientists induce exotic behavior from conventional 2D materials by very carefully controlling the electron density and screening environment.

“For example, if we take a single layer of a transition metal dichalcogenide (TMD) and put electrons in it at a very low density, then the electrons crystallize into a pattern called a Wigner crystal,” says Crommie. “That’s a very exotic behavior where the electrons freeze like ice but still move around.”

**BUILDING EXOTIC 2D MATERIALS**

How to create exotic 2D materials is not obvious, but Crommie offers some guidance.

“In most conventional materials, the periodicity—the distance between the atoms and how they’re arranged in the lattice—determines the behavior. Electron-electron interactions and topology don’t play a big role,” says Crommie. “We make so-called exotic 2D materials by modifying these properties using techniques developed in recent years, using three general approaches.”

In the first approach, the researchers stack and rotate atomically-thin layers of different materials to create what is called a 2D moiré superlattice. Strong covalent bonds provide in-plane stability, whereas relatively weak van der Waals forces hold the layers together. And a small mismatch in the spacing of the atoms between the layers produces an interference pattern—like when you put two screens together and rotate one—thus creating a new superlattice periodicity.

“Moiré superlattices allow us to engineer new lattices for electrons and to control their correlation behavior,” says Wang. “We’re building quantum materials by design with an unprecedented control that doesn’t exist in nature.”

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“Having access to higher resolution tools and new ways of probing materials is how we make new discoveries. It’s a must if you want to lead the way to new science.”

into a new crystalline phase, because the potential energy dominates over the kinetic energy. Wigner crystals were predicted almost 90 years ago, but we can image them now in new 2D materials.”

In the third approach, they create novel excitonic states in topological insulators, materials that behave like an insulator in their interior but conduct electricity along their surfaces.

“On the surface of a topological insulator, it’s like there are two freeways for electrons. Electrons with one spin move in one direction, and electrons with the other spin move in the opposite direction,” says Lanzara, the Charles Kittel Chair in Physics. “Our goal is to use optical pulses and leverage the topology and bulk surface properties of these materials to engineer new quasiparticles.

DEVELOPING NOVEL TOOLS
To build and investigate a diverse range of exotic 2D materials, Berkeley physicists are pioneering new techniques. “Having access to higher resolution tools and new ways of probing materials is how we make new discoveries. It’s a must if you want to lead the way to new science,” Lanzara says.

These experimentalists have favorite tools; for example, Wang specializes in studying how light interacts with materials.

“We use optical photons from near microwave to UV,” says Wang. “The combination of optical modalities depends on the material and the specific questions we’re trying to answer.”

Optical spectroscopy is Wang’s primary technique. But his group also uses scanning tunneling microscopy (STM), including a novel non-invasive spectroscopy technique he developed with Berkeley Physics Professors Alex Zettl and Michael Crommie.

Together they built a moiré superlattice from single layers of tungsten diselenide and tungsten disulfide and then added a spacer layer of boron nitride capped by a top layer of graphene. The graphene layer enabled them to sense a delicate crystal of electrons within the TMD moiré structure without destroying it with the STM tip. The spacer layer prevented electrical shorting and permitted independent doping for the TMD and graphene layers.

“We made the first real-space images of 2D Wigner crystals in our moiré superlattice by actually imaging a lattice formed by electrons. We were able to see the correlated ground state and interesting excited state properties,” Wang says. This approach could also be used to image electron lattices in other materials, rather than relying on a “magic angle” between the layers to control the correlations.

“Our TMD moiré superlattices exist at zero twist angle due to the lattice mismatch, and the correlation effects remain strong,” says Wang. Berkeley physicists are also directly measuring electrons and spin in momentum space using novel spin-, time-, and angle-resolved photoemission spectroscopy pioneered by Lanzara and her coworkers. In this technique, a material is irradiated with a beam of ultrashort photons and the spin, speed, and direction of the ejected photoelectrons are measured with incredible sensitivity to figure out what’s happening inside the material. Lanzara’s latest instrument, named the momentum microscope, can also look at real space.

Lanzara recently used her state-of-the-art system on the topological insulator bismuth telluride to search for novel types of excitons, which are charge-neutral quasiparticles created when light is absorbed in a semiconductor. Her team discovered and characterized the first spatially indirect topological exciton state. “The electron trapped on the surface is coupled to a hole confined in the bulk, generating a long-lasting spatially-separated exciton that retains the special spin properties inherent to topological states,” she says.

One potential application of exotic materials is sustainable electronics that stays cool. “Your cell phone and computer heat up because charges bounce into each other as they move,” explains Lanzara. “Some of these new 2D and topological materials allow information to be transported instead through spin, minimizing interactions and eliminating heating issues. Moreover, they can be combined into Logo-like blocks, enabling easy assembly of materials on demand that are reusable and recyclable.”

Just think, you might have an exotic 2D material in your pocket someday.
Testing Gravitational Time Dilation with Array of Miniature Clocks

Einstein’s theory of general relativity predicts that gravity causes time to pass more rapidly for a clock higher off the ground than an otherwise identical lower clock. Correcting for this relativistic effect is vital to the location accuracy of global positioning systems (GPS) because it causes the clocks in satellites to tick faster than their counterparts on the ground. But gravitational time dilation is also important to theoretical physics.

“We’re still trying to understand how general relativity and quantum mechanics fit together. They’re both incredibly successful theories whose predictions have thus far always proven to be true, but they’re fundamentally at odds with each other,” says Shimon Kolkowitz, Berkeley Physics associate professor and the Roger Herst Professor in Physics. “So, we’re exploring the interface between quantum systems and relativity.”

Kolkowitz recently tested gravitational time dilation in his lab using a novel quantum clock network—composed of five evenly spaced ensembles of ultracold 87 strontium atoms trapped in a vertical 1D optical lattice that spanned a total height difference of 1 cm. Using an array of clocks with the same atomic resonance, optical lattice, vacuum chamber, and apparatus allowed his team to measure the rates the clocks were ticking with respect to each other with 19 decimal places of precision and accuracy.

“We corrected for all the systematic shifts using pairwise comparisons and we unbinned our data, our more precise and accurate results confirmed time passes more rapidly for a clock 2.5 mm higher off the ground in a way that’s entirely consistent with the predicted gravitational time dilation,” says Kolkowitz.

“We have a whole new playground for exploring relativity and quantum mechanics. For example, what happens when the atoms are experiencing different heights simultaneously? We’re also developing new applications for these clocks, including searching for dark matter.”

Generating Two-Qutrit Entangling Gates for Quantum Computing

Like Schrödinger’s famous cat, a quantum bit (or qubit) can exist in a simultaneous superposition of two states. Quantum computers entangle many qubits together, causing them to become correlated at a quantum level and no longer describable as individual systems.

By exploiting large-scale entanglement, researchers can generate increasingly complex quantum states. Ultimately, their goal is to build quantum computers capable of quickly solving problems too complex for even the most powerful conventional supercomputer.

Most research on the design and control of quantum processors currently focuses on two-level qubit systems. But a collaboration of researchers at UC Berkeley’s Quantum Nanoelectronics Laboratory and Berkeley Lab’s Advanced Quantum Testbed are now using three-level (qutrit) systems to develop a superconducting quantum processor.

“Three-level quantum information processors potentially offer significant advantages in quantum simulations, error corrections, and algorithms,” explains Noah Goss, a Berkeley Physics graduate student involved in the work. “Establishing two qutrits, however, is challenging because the quantum system is more complex, so we had to introduce a new approach.”

Recently, the Berkeley team achieved a breakthrough by implementing a faster, flexible, and tunable entanglement between two qutrits. They then used their approach to engineer two types of two-qutrit logic gates.

"Entangling two qutrits, however, is challenging because the quantum system is more complex, so we had to introduce a new approach."
Scientists have been studying the cosmos for centuries, but we still don’t know what makes up 85% of all matter in the universe. Unlike ordinary matter that we can see and feel, dark matter hasn’t been observed directly by even our most advanced scientific instruments. These invisible particles may be slipping through us all the time without interacting.

But scientists believe our world wouldn’t exist without dark matter. Its gravitational pull holds galaxies together, gathers them into clusters, bends light around them, and affects how they rotate. Dark matter also played a crucial role as galaxies initially formed.

“Lots of observational data show us that dark matter is a real particle, but we don’t know what kind. Its possible mass has a huge range, and there might be multiple types of dark matter particles,” says Berkeley Physics Professor Dan McKinsey, the Georgia Lee Chair in Physics. “We’re working hard to detect dark matter in the lab to open a window into new physics. It’s the only particle we know to exist outside the standard model.”

Berkeley Physics is one of the top places in the world to study dark matter. Experimental and theoretical physicists at Berkeley are leading far-reaching searches—hunting for dark matter candidates ranging from 1 TeV weakly interactive massive particles (WIMPs) to 1 MeV light dark matter particles down to 10 µeV axions.

Berkeley faculty are conducting, building, and designing next-generation dark matter experiments, including the LZ, SuperCDMS, TESSERACT, and ALPHA plasma haloscope. These innovative experiments are guided by models developed by Berkeley Physics theorists, including professors Hitoshi Murayama, Lawrence Hall, and Ben Safdi.

We highlight only a few of these comprehensive efforts here.

Hunting for WIMPs with LZ

One promising candidate is WIMPs, weakly interacting but heavy dark matter particles with a predicted mass of about 10 GeV to 100 TeV. A GeV is roughly the mass of a proton.

Hunting for WIMPs over 9 GeV is the aim of LZ, the larger and more sensitive successor of the LUX experiment. After 60 days of running, LZ recently became the most sensitive dark matter detector in the world. Berkeley Physics Professor and Berkeley Lab Director Mike Witherell, Emeritus Professor Bob Jacobsen, and McKinsey contributed to this success.

Because dark matter particles rarely interact with ordinary matter, their signal is easily drowned out by background noise. To shield from cosmic rays, LZ is located nearly a mile underground at the Sanford Underground Research Facility (SURF) in South Dakota. To reduce radioactive contamination, it uses ultra-clean detector materials. And to lower environmental backgrounds, it is built in several layers like an onion.

At the center of LZ is a time projection chamber (TPC)—a tank filled with seven tons of highly-purified liquid xenon. If a dark matter particle strikes a xenon nucleus, a flash of light and an electric charge are produced as the nucleus recoils. A strong electric field drifts the charge to the top surface of the TPC, where the electrons create a much larger flash of light that is measured by photomultiplier tubes on top and bottom.

The pattern and timing of the two flashes pinpoint the position and energy of the event. And the ratio of the two scintillation signals determines if the event was caused by a nuclear or electron recoil.
Outside the TPC are two veto detectors—a “skin” holding three tons of liquid xenon and an "outer detector" of gadolinium-loaded plastic scintillators. The resulting increase is used to reject signals from gamma rays and neutrons, respectively. The whole thing lies inside a massive tank of water.

LZ is 15 times larger than the previous generation LUX experiment, which helps suppress backgrounds. But this increase also created a major challenge for McKinsey, designing and building a much higher voltage system to get the correct drift electric field, without the xenon lighting up like a neon lamp.

McKinsey also led the data analysis effort to reduce “accidental backgrounds” with support on backgrounds from Berkeley Physics Professor Emeritus Bernard Sadoulet, Ph.D. candidates Areli Olcina and graduate students Jose Sofia, Yue Wang, Ryan Gibbons, Ryan Smith, and James “Breed” Watson. “Occasionally, isolated first and second scintillation pulses randomly pair up to look like a dark matter event,” explains McKinsey. “My group combed through cryogenic liquid data, produced a statistical model, and developed cuts to reduce these accidental events before cutting into our dark matter acceptance.”

So far, LZ has found no evidence of WIMPs, but it set the most stringent limits on WIMP cross-sections and masses to date. And the second 1000-day run is underway.

"LZ is performing to specification, which is a big deal since we’ve been working on it for a decade," says McKinsey. “We’ve now pushed to through more dark matter particle mass over the next few years.”

McKinsey is also helping to design the next-generation of LZ, a scaled-up 80-ton xenon experiment called XL2D.

SEARCHING FOR LOW-MASS WIMPS WITH SUPERCDMS

SuperCDMS, the next-generation of the CDMS experiment, is located deep underground at SNOLAB near Sudbury, Canada. It plans to detect dark matter particles with a mass between 10 GeV and 0.5 GeV. Berkeley Physics Professor Emeritus Bernard Sadoulet led the NSF-funded part of its construction.

Searching for dark matter with lower mass requires more sensitive detectors. SuperCDMS uses germanium or silicon crystals attached to sensors on both faces. When a dark matter particle interacts with either semiconductor, its nucleus recoils and creates an athermal phonon vibration (phonon) and ionization (charge). An electric field causes the charge to drift and shed lots of phonons.

“Measuring both phonons and ionization gives us discrimination capability against backgrounds. And drifting the charges in the high-voltage detector increases our energy sensitivity by a factor of 20, allowing us to search for lower masses,” says Sadoulet.

Unfortunately, measuring those phonon signals is challenging. Berkeley Physics Assistant Professor Matt Pyle played a major role in developing this unique superconducting transition-edge sensor (TES) technology, for the SuperCDMS experiment.

Top: A prototype He4/LCD detector mounted to a dilution refrigeration system. Middle: A calorimeter array (4 X 4) with transition-edge sensor (TES) readout for the He4/LCD experiment. Bottom: Shown here as semi-transparent squares, a sapphire dark matter detector held within a larger transparent copper mount are used by the Malle Lab as part of the sHECD experiment.

SEEKING LIGHT DARK MATTER WITH TESSERACT

TESSERACT intends to detect the dark matter signal with a step-by-step approach. There are several different experimental phases to this being designed to detect light dark matter particles from both nuclear and electronic recoils, in the range of 1 GeV to 1 keV.

“TESSERACT aims to detect low-mass dark matter particles by looking for coincidences between the signals of individual ion pairs in the detector. That’s the secret sauce of TESSERACT,” says Pyle. “We’re also eliminating a whole class of background events, by going to the cold field, which means we need very highly sensitive detectors.”

McKinsey’s group is helping develop TESSERACT’s He4/LCD detector arrays, developed from Assistant Project Scientist Jumong Lim and graduate students Roger Romani, Will Marangelli, Zeyu Wei, and graduate student Yujin Park. He4/LCD are polar crystals that can absorb the energy of the vibrations, concentrate it, and then use the heat it generates to cause the TES temperature changes its resistance, which is measured by cyroganic electronics.

“Those phonon signals need to be small enough to reduce their heat capacity. But if they’re attached directly to a giant, external phonon sources around for a long time before they interact with the TES. By using a fast process, we increase the interaction probability and area coverage,” says Pyle.

“The key is to capture the phonon quickly before they thermalize.” McKinsey’s group is currently installing the experiment at SNOLAB. Meanwhile, they have been commissioning the SuperCDMS detectors, software, and operations at CUTE, a nearby cryogenic underground test facility at SNOLAB.

Sadoulet notes that Berkeley Physics colleagues have contributed to the research and data analysis transfer between various groups. The core astrophysical phonon sensor technology and discrimination methods are being used in multiple experiments, including SuperCDMS and TESSERACT.

“What makes TESSERACT unique is that every detector is designed to have multiple signal channels that we can use for coincidence for dark matter events. That’s the secret idea sauce of TESSERACT,” says Pyle. “We’re also eliminating a whole class of background events, by going to the cold field, which means we need very highly sensitive detectors.”

Despite running on supercomputers, computer memory is a limiting factor. Luckily, Safdi turned to the AMReX collabiration at Berkeley Lab, adapting their code framework designed for the multi-scale problems. The key was using an adaptive mesh grid with a fine spatial resolution around the axion strings and sparse resolution elsewhere. Using the largest simulation of axion strings to date, they more precisely predicted the axion mass to be between 100e- to 1000e-times higher than expected. This claim in axions from the early universe can’t be detected by the current experiments, which use a microwave resonance chamber to enhance the photon frequency coming from axions. The required chamber would be too small to get a measurable signal.

However, Safdi’s prediction excited Berkeley Nuclear Engineering Professor Karl van Bibber. He is building the ALPHAla plasmonic haloscope, which creates resonant enhancement using parallel wires in a strong magnetic field. And van Bibber is waiting to tune his experiment using the more precise predictions Safdi is now calculating with He4/LCD.

Overall, Berkeley Physics search for dark matter is casting an impressively wide net. “Berkeley might be the best place in the world for dark matter searches,” says McKinsey. “We have lots of jobs up here full climbing away. It’s a game changer for our mass predictions, compared,” says Safdi.

One feature he needs to simulate in the early universe is axion strings, which are very thin but narrow regions of space—like tiny tornadoes—that whip around and emit lots of axions.

“During the simulations, a small part of the expanding universe is represented by a 3D grid over which the equations are solved,” explains Safdi. “But the axion strings are moving, so we have to dynamically update the grid. Despite running on supercomputers, computer memory is a limiting factor.”

Although Safdi is a theoretical physicist, he looks for indirect signatures of dark matter in experimental data with his team, including graduate student Joshua Benabou. “My work starts theoretically, with pencil and paper. Then we analyze the data to see if the axions interact with neutrons and light.”

“If axions affected neutrons, then they would affect the interactions of axions in other ways. So we build a list of all the things they could do, and then test them in the lab,” says Safdi. “We’ve developed a new technique to detect the axions—using an impressively wide net. “Berkeley might be the best place for dark matter searches, I can’t think of any place that’s stronger overall and better,” says McKinsey.
AS AN UNDERGRADUATE at UC San Diego, I knew I wanted to work in science or engineering but I wasn’t sure what I specifically wanted to do “when I grew up.” That’s why I majored in physics—it’s versatile.

After earning a PhD in physics at UC Santa Barbara, I worked for years as an academic researcher at Lawrence Berkeley National Lab (LBNL). I later veered off this career path, merging my passions for science and writing. On the surface, my physics degrees may seem unnecessary for a science journalist, given that I mostly write about medical research. But my physics training is integrated into how I research, interview, and write. So, I was intrigued to speak with several Berkeley Physics alumni doing non-academic jobs to see how they apply their physics degrees.

Marc Peters is an intellectual property attorney at Turner Boyd LLP. He helps clients resolve disputes related to technology, including those involving patents, trade secrets, and copyrights.

According to Peters, “thinking like a physicist” means approaching issues with the right level of abstraction, which helps determine what matters, what does not, and what is “good enough.” It also requires the curiosity to always ask “why.” These are key skills for a successful litigator.

“I was fortunate to have Professor Marjorie Shapiro as my advisor and to work with the CDF group at LBNL. They taught me how to break down any problem into solvable chunks and how to work with a group of really smart people, which I am fortunate to still do,” says Peters. “And my electronics, semiconductor, programming, and teaching experience helps me understand my clients’ technology and helps me communicate it to non-technical judges and juries.”

Peters offers some advice to current students: “Physics education and training will serve you well in whatever profession you want to pursue.”

“Physics also helped me think more clearly and become a stronger problem solver,” she says. “Its generality means approaching issues with the right level of abstraction, which helps determine what matters, what does not, and what is ‘good enough.’”

Marc Peters is a Senior Technical Fellow at the Boeing Company. He is essentially a professor in an international company. He publishes, gets patents, gives talks, and interfaces between the technical and managerial sides of the company—always pushing the frontiers of their technology.

According to Hunt, Berkeley Physics training contributed to his success in industry. “I learned how to see the big picture, be creative, and solve problems,” he says. “My training was also very broad—optics, electronics, computer algorithms, and more—which has enabled me to reinvent myself, move around, and advance at Boeing. A physics degree is the liberal arts degree for the new millennium.”

Hunt also appreciates that his Berkeley Physics group included students and postdocs from around the world, preparing him for global collaborations.

Naseem Gaafar Chopra is the Vice President of Systems Engineering and Sustainability at Applied Materials. She spends most of her time in meetings, where she relies on the fundamentals that she learned at Berkeley Physics to successfully understand and engage in technical discussions.

“Physics also helped me think more clearly and become a stronger problem solver,” she says. “Its generality helped me get an entry ticket to jobs. And I get a lot of respect as a capable person because physics is challenging.”

Since getting her PhD in physics at Berkeley, Chopra has worked in various roles, industries, and companies, including a Silicon Valley startup, Apple, the solar industry, and the semiconductor industry. She is now excited to share this industry experience as a new member of Berkeley’s College of Letters and Science Advisory Board.

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Highlighting Rising Stars in Physics

Berkeley Physics was delighted to host the 2023 Rising Stars in Physics Workshop this spring, sponsored by the Heising-Simons Foundation. This event brought together 40 outstanding women physicists and astronomers for two days of scientific talks and informal discussions aimed at helping them navigate the early stage of their academic careers.

The workshop was led by Pablo Jarillo-Herrero, associate professor of physics at MIT and founder of the workshop series, and Alessandra Lanza, professor and Charles Kittel Chair in Physics at UC Berkeley. Lanza's personal experiences motivated her to help organize it. "My first years at Berkeley were difficult with too few role models in my department. I often felt lonely and like I didn't belong," says Lanza. "These types of workshops help create a network for young women to share experiences, challenges, and ideas with their peers and senior colleagues to help them succeed."

The highlight of the workshop for many of the participants was getting to know each other—through workshop sessions and casual interactions over meals or in an airport shuttle. "Meeting my physics peers from different fields was amazing," says Veronika Sunko, Miller Postdoctoral Fellow. "The atmosphere was different with 80% of the people in one room," she says. "It was fun." Sunko is a condensed matter experimentalist studying quantum materials with Berkeley Physics Professors Joe Chemla and James Analytis. "We use lasers to learn about the magnetism of materials that exhibit an interesting interplay of magnetic and electronic degrees of freedom, yielding new phenomena that we're working to understand," she says. "Mulan Zhang, postdoctoral researcher at the Berkeley Center for Theoretical Physics, enjoyed the keynote speeches by senior investigators. "Very accomplished people talked in-depth about their career trajectory and the massive-scale projects they're overseeing," says Xu. "I also appreciated the participants' talks. I rarely hear about research outside my narrow niche of theoretical particle physics.""Xu works on various projects with different collaborators, using astrophysics and cosmology tools to study the particle nature of dark matter. "For example, I collaborate with Berkeley Physics Assistant Professor Ben Safdi. We're analyzing data of gamma rays that come from the middle of our galaxy to search for Higgs-dark matter," explains Xu.

As a new postdoc at the Harvard Society of Fellows, Carolyn Zhang soaked in career tips from workshop panelists on how to apply for faculty positions, build a research group, and balance commitments. "It was helpful to hear about different people's unique journeys to where they are today. And it was cool to see so many women physics professors in one room," she says. As a condensed matter theorist, Zhang studies the quantum phases of matter and the transitions between them. But her interests are broad and her fellowship is not tied to a single department. Zhang also appreciates the volunteers who devoted time to organize the workshop. "They seemed genuinely passionate about supporting women entering the physics field, which was very encouraging."

Berkeley Physics welcomes 2 new faculty members

RAÚL BRICEÑO

Raúl Briceño was born and raised in Caracas, Venezuela. In 2019, he received his PhD in physics from the University of Washington. He then joined the Center for Theoretical and Computational Physics at Jefferson Lab as a postdoc. In 2020 he became the Nathan Isgur Research Fellow at Jefferson Lab and in 2021 he started an assistant professor position at Old Dominion University. His research largely focuses on aspects of theoretical nuclear and particle physics. He joined Berkeley Physics as assistant professor in January of 2023 with a joint affiliation in the Nuclear Theory group at Lawrence Berkeley National Lab.

SHIMON KOLKOWITZ

Shimon Kolkowitz earned his PhD in experimental physics at Harvard in 2015. He was a postdoctoral fellow at JILA/NIST/CU Boulder. He started a faculty position in the Department of Physics at the University of Wisconsin, Madison in 2018 as an assistant professor, and was promoted to associate professor with tenure in 2022. Shimon's research focuses on quantum sensing, precision measurement, and metrology.

He joined Berkeley Physics in July of 2023 as associate professor and is the Roger Herst Professor in Physics.
AlumniStories

Alum Gina Quan Fosters Student Leaders and Inclusion

Gina Quan moved into her Berkeley dorm two weeks before freshman year in 2008 to participate in the Compass Project’s early start program for freshmen interested in physical sciences. “This amazing student-led organization fosters student leadership and inclusion, particularly for students who are underrepresented in physics,” says Quan, assistant professor of physics at San José State University. “It was an incredible way to start at Berkeley because I created a support network of close friends. And when you encounter people that you work well with and share values with, you just never let them go.”

InMemory

Alan Kaufman (1927–2022)

Alan Kaufman, a former Berkeley Physics professor, passed away on December 2, 2022. As an undergraduate and graduate student at the University of Chicago, Kaufman worked with numerous great theoretical physicists, including Enrico Fermi, Gregory Wentzel, and Marian Goldberger. After receiving his PhD in 1953, he took a position at the newly formed Livermore Laboratory where he worked on Project Sherwood—the US program to develop controlled nuclear fusion—and other fundamental research programs. He started teaching at Berkeley in 1957 and joined the faculty in 1959. As a Berkeley Physics professor, he mentored graduate students who went on to become major figures in the field of plasma physics, including Chuan Liu and Ron Davidson. During his long career, he was recognized as an insightful pioneer who made many seminal contributions to theoretical plasma physics. Kaufman became Emeritus in 1998.

Alumnus of the Year
John Mather

Berkeley Physics alum John Mather has won many prestigious awards—including the 2006 Nobel Prize in Physics with George Smoot for taking precision cosmic background radiation measurements that supported the Big Bang Theory of the expanding universe. But receiving this year’s UC Berkeley Alumnus of the Year award in front of an audience of longtime friends and former Berkeley colleagues was still special. “It was a joy to see my thesis advisor Paul Richards, of longtime friends and former Berkeley colleagues was still special. “It was a joy to see my thesis advisor Paul Richards, and when you encounter people that you work well with and share values with, you just never let them go.”

Compas Project participants later created similar groups at other universities—including the Equity Constellation co-founded by Quan at the University of Maryland as a graduate student—and connected them by forming the Access Network. Through the Compass Project, she met Berkeley Physics alum Angie Little, who introduced her to physics education research and who is a co-principal investigator on Quan’s new project recently funded by the National Science Foundation’s Racial Equity in STEM education program.

In partnership with Michigan State University, Quan and Little will soon study how physics departments can better support and retain transfer students of color. “We’ll form transfer advocacy groups (TAGs) of students, faculty, and staff who will develop new ways to support transfer students. We don’t know what will emerge from these TAGs because students tend to be the forefront of designing change,” she says. The researchers also want to better understand and document the experiences of these understudied students. They plan to disseminate their findings via journal articles and podcasts.

Quan clearly values empowering student leaders; on both a professional and personal level. “I learn so much from my incredibly smart and brilliant students at SJSU. I’m excited for the world they’re going to create and lead,” she says.

In Memory of Alan Kaufman

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