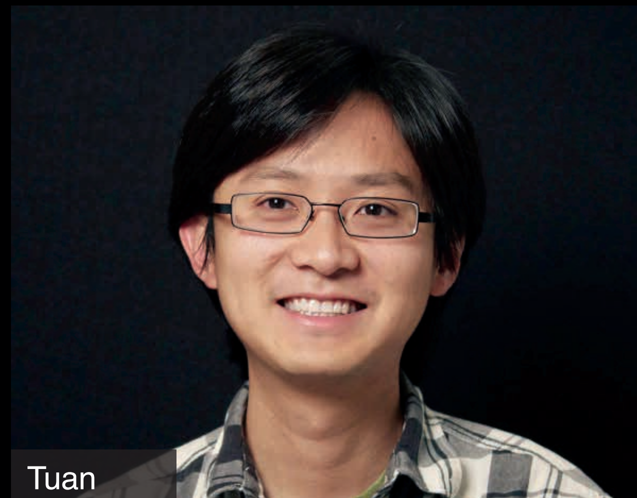
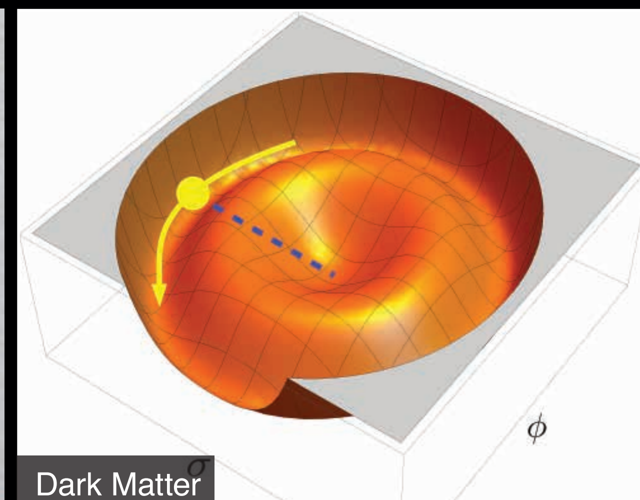

Andrea


Tuan


Michalis


Black Hole


Ni Ni


Dark Matter


Alice


Juan Pablo

UCLA College | Physical Sciences
Physics & Astronomy

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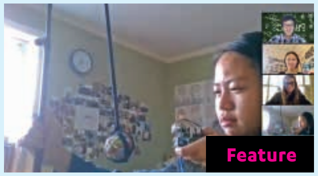

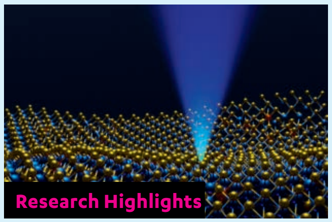

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Cover: The department sometimes feels like the Brady Bunch on our zoom screens. Top row: Prof. Andrea Ghez, Prof. Tuan Do, Prof. Michalis Bachtis. Center row: A black hole, Prof. Ni Ni, some dark matter. Bottom row: Prof. Alice Shapley and graduate student J.P. Gatica.

Design: Landesmann Design

CHAIR'S MESSAGE

WE BRING TO YOU OUR "REFLECTIONS" on the last academic year, which has been like none other. Our courses suddenly went remote in March in response to the COVID-19 pandemic. I am happy to share with you how well the faculty and students responded. Many felt lectures with a tablet plus stylus, backed up with live chat windows, went at least as well as ever. Our at-home laboratories proved that physics works everywhere, not just in Knudsen Hall and the Physics & Astronomy Building. And our astronomy students, scattered around the world, still had the sky and planet to work with. We devote our feature article this year to how this went.

The new stay-at-home learning was hard on everyone, especially those sharing their space with young children or siblings. I sympathize. And I am proud of how everyone made and continues to make their best of it. While the club meetings, graduations, study sessions, seminars, and special events have persisted by videoconference, we miss each others' company in person and look forward to better days.

I especially thank at this time the generosity and foresight of our supporters. Your donations meant we had funds in-hand to solve many problems by purchasing needed equipment on a moment's notice. Individual undergraduate and graduate student challenges were also solved in a number of creative ways, since we had the financial means under our own control. That flexibility was vital.

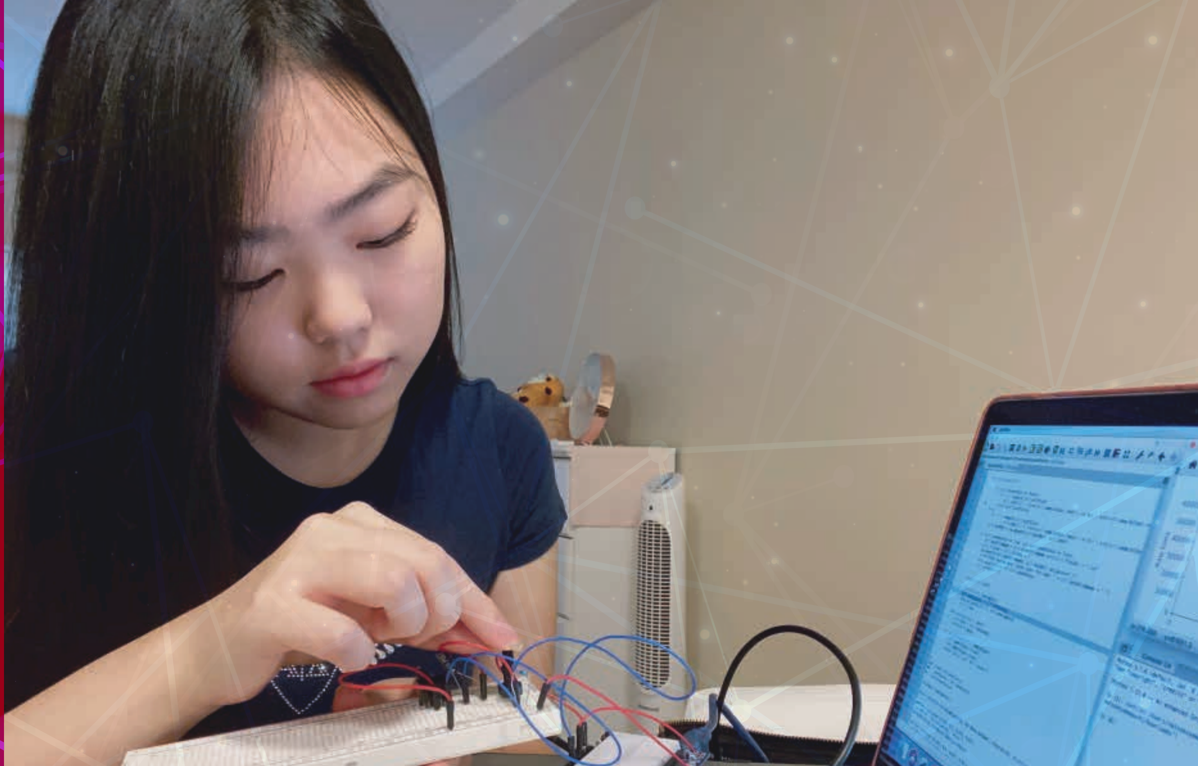
We are over the moon with the breaking news of Prof. Andrea Ghez's 2020 Nobel Prize in Physics. Because this came in during the following academic year, just as we went to press, we have included a brief review for now. We are planning a full celebration in next year's Reflections magazine.

As we enter the third year of this departmental administration, I want to thank the Vice Chairs for all they have done in the past years and during this special time: Prof. Wes Campbell for Resources oversaw the careful research ramp-up safely, following health department protocols. Prof. Jay Hauser for Academic Affairs solved new challenges with remote teaching and learning. And Prof. Alice Shapley took care of all the myriad needs of Astronomy & Astrophysics, including helping new astronomy faculty launch their careers successfully under these difficult circumstances.

I also thank our staff who worked through this unexpected difficulty and kept the department humming. We welcomed new members and bid farewell to many dear friends who contributed for decades.

This magazine cannot cover everything. I invite you to visit our webpages at https://www.pa.ucla.edu/ to learn more about what our 150+ graduate students, 100+ undergraduates per year, 40+ researchers, project scientists, and adjunct faculty, 50+ postdoctoral scholars, and 50+ staff have been doing to continue making this department excellent and unique.

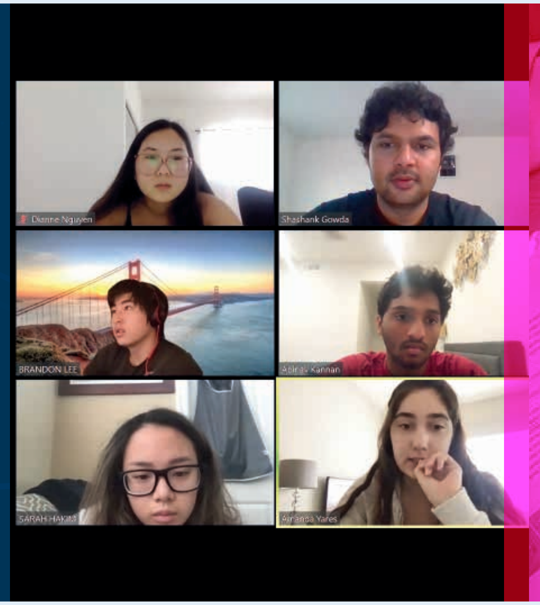
Warm regards,
DAVID SALTZBERG
Chair, Department of Physics and Astronomy



Caring, Creative, & Connected

WHEN THE COVID-19 PANDEMIC forced campus to close and sequestered us in our homes apart from one another, it became all the more valuable to appreciate that physics and astronomy can be observed no matter where we are in the world.

> **"These are trying times and require flexibility by all. Faculty that have made their concern for their students shine through started off on the right foot and with a bank of goodwill."**
>
> – **David Saltzberg**, Department Chair



Previous page: Students in the Physics-4AL/BL labs study introductory physics using Arduino processors.

Above left: Students paying close attention. Above right: A student in Physics 180F makes her own cosmic-ray detector.

BUT OBSTACLES TO PROVIDING SUBSTANTIVE INSTRUCTION on these subjects are daunting. How do you persevere through unimaginable conditions to educate students well? What do you have to do to provide students with the top-level academic excellence that UCLA and the Department of Physics & Astronomy always strive for?

Unparalleled innovation and discovery are hallmarks of our department. During spring quarter 2020, these qualities have helped students, faculty, and staff come together and continue teaching, learning, researching, and working in concert as a community dedicated to science.

"These are trying times and require flexibility by all. Faculty who have made their concern for their students shine through started off on the right foot and with a bank of goodwill," said Dept.Chair David Saltzberg.

The switch to fully remote coursework required a superhuman effort on the part of teaching assistants (TAs), who are not only a critical arm of instruction but also students themselves. To support their monumental efforts as teachers and key troubleshooters for both students and faculty, the Physics & Astronomy Dept. gave extra stipends to all 77 of its TAs, a gesture made possible thanks to the support of donors who have invested in the department. Donor gifts also allowed the department to purchase iPads and Apple Pencils so that the TAs would have devices to teach with.

Now that Zoom has become as ubiquitous as email and phone calls, it's hard to recall daily life without it. When the stay-at-home order went into place in March, those who knew what Zoom was, much less had familiarity with it, were in the minority. Capturing the attention of students trying to learn while surrounded by distractions in less-than-ideal living environments was an immediate challenge. Part of the unforeseen work taken on by TAs was tutoring faculty on how to couple the Zoom video conferencing with iPad tablets to deliver effective and engaging lectures.

Their information sessions walked faculty through the most basic Zoom functions, from creating meeting invitations and breakout rooms to screen sharing to camera settings – plus, of course, muting or unmuting your microphone. Again, knowledge that's easy to take for granted now, but was not in nearly anyone's wheelhouse at the start of the year.

The TAs also shared tips for making the most of iPad apps that allow for whiteboard-like functionality and real-time annotation to help make the lecturing experience as similar as possible to in-person. Both faculty and TAs have come out of the experience with new sets of digital skills that will remain handy well beyond the pandemic.

Providing solid instruction when it came to labs was an additional hurdle. All lab classes became virtual with no students able to access to the laboratories or equipment they would have on campus. While that restriction was daunting, Physics & Astronomy faculty put their inventiveness to work, modifying existing experiments or creating brand new ones that made the most of mobile phones and common household supplies.

Prof. Jean-Luc Margot took the 5th edition of his search for extraterrestrial intelligence (SETI) course to the online-only format, conducting interactive Python exercises and utilizing the powerful Jupyter app for students to analyze and visualize data. The storage server purchased last year with donor support was key to these efforts, as was a team of three instructors, including a newly-funded TA. The SETI course culminated in final presentations describing exceptionally strong student software contributions to the data processing pipeline, demonstrating progress comparable to its historical spring 2016 class, which developed a data-processing pipeline from scratch.

Prof. Rene Ong and postdoc Sean Quinn scrambled to put together a remote laboratory for students enrolled in Physics 180F – Elementary Particle Laboratory. This course normally involves detecting and studying cosmic-ray particles in a laboratory on the fourth floor of Knudsen Hall. Since campus facilities were not available, theydeveloped a kit of equipment and a set of experiments that could be done at home.

The experimental kit contained the necessary components to build and operate two scintillation counters. Included were blocks of scintillator (plastic material that releases light when a charged particle goes through it), photomultiplier tubes to detect the scintillation light, the electronics to power and read out the photomultiplier tubes, and supplies such as electrical tape, wire strippers, and aluminum foil. A key component was a USB oscilloscope that permitted the capture of high-speed waveforms. Students just needed a laptop and some imagination to carry out the experiments.

The initial tasks for the students included the construction of the counters, testing and checking them, and making a careful study to determine proper operating point for both counters. The students measured the cosmic-ray rates for single counters and for the two counters in coincidence, the dependence of cosmic-ray flux on arrival direction, the effect of operating the counters inside a building and outside, and the time dependence. An important part of the lab was to compare the measurements taken with expectations made by the students using both a simple calculation for the detector acceptance and a more complicated model that used the Geant4 package, the standard tool for detector simulation in particle physics.

From the good results obtained in spring quarter and the very positive feedback from the students, Ong decided to repeat the remote lab in fall 2020, with a more complete kit and improved documentation.

After the close of an unprecedented quarter, such passionate dedication to student success was acknowledged by positive evaluations. Students awarded courses and instructors with scores higher than for those same courses in spring 2019.

"Instructors who can openly share the difficulties of teaching remotely, and make allowances for the difficulties that students are having learning remotely, have had happy experiences," said Prof. Jay Hauser, who serves as the department's Vice Chair of Academic Affairs and helped guide the department's shift to remote learning.

Surveying students about their internet access, computer availability, and overall technical capabilities, and time zones, helped everyone navigate the transition with more awareness and patience. Experimentation with asynchronous lectures, flash polls or quizzes, live lectures alongside pre-recorded videos, and much more kept teachers and learners alike motivated and empowered to take advantage of all that technology had to offer.

And while nothing takes the place of being with someone in person, modern technology has given us ways to continue fostering community within the department. As daily routines, tasks, and demands shifted, unimagined opportunities became available. For example, the dept. chair was able to host weekly office hours to discuss everything from exams to graduation. He was joined not just by curious and concerned students but also faculty, staff, and postdocs. The office hours proved so popular that there was no doubt they would continue beyond the school year.

A weekly journal club called DiversiTea offered a space for sharing and discussing diversity, equity, and inclusion. Undergraduate and graduate students, faculty, and staff came together on Monday afternoons to share information and resources for navigating topics such as intersectionality, privilege, and minority representation.

Graduate student recruitment continued in new ways even though prospective students could not come to campus or meet anyone in person. Astronomy graduate students recorded a short video featuring a virtual tour of the Astronomy Division. Interviews with potential new faculty were also conducted remotely. "In fact, we are joined by a candidate who didn't visit in person: Dr. Paulo Alves," Saltzberg said.

The academic year ended not with a commencement, but with hope for an in-person celebration in 2021 to make up for the difficult circumstances this spring. The occasion was marked by what the department called a "non-commencement reminiscence event" on June 14, bringing the Physics & Astronomy community together to share laughs, tears and a passion for science connecting us all no matter the distance keeping us apart.

Continuing this momentum into the fall, Prof. Erik Petigura created a lab for the Freshmen Cluster 70 course, Evolution of the Cosmos and Life. "Students separated by hundreds of miles collaborate over Zoom to measure the size of the Earth with sticks and shadows. Here, remote instruction is a feature, not a bug," he says.

THE SUCCESS OF PHYSICS 4AL/4BL & 5AL/5BL/5CL

Instructors' foresight leads to remote learning success for physics labs. COVID-19 pandemic further confirmed the benefits of letting students design their own experiments.

By Adrian Figueroa • Originally published in UCLA Newsroom, June 10, 2020 [excerpted]

WHEN UCLA ANNOUNCED ON MARCH 10 that the final weeks of winter quarter — and later the entire spring quarter — would be taught remotely because of COVID-19, it immediately tested everyone on campus, but in particular students and faculty who had to figure out on the fly new ways to learn and teach.

Adapting was understandably easier for some classes, like introductory courses which could more simply turn a live lecture in a big hall into a video lecture delivered through Zoom. But what about classes built around in-person group work, or the performing arts, or science and engineering labs that require the use of equipment and materials for hands-on learning?

"The key to giving a satisfying experience to students working remotely is to offer real-time solutions as quick as possible," said Katsushi Arisaka, professor of physics and astronomy in the UCLA College and also of electrical and computer engineering in the Samueli School of Engineering, who emphasized how much of a team effort this has been. "That's why we need such a good group of TAs behind the scenes."

For Arisaka, restructuring these classes has always been about finding new ways to prepare students for future success. He has worked with teaching assistants Javier Carmona, Shashank Gowda, Erik Kramer, Grant Mitts, Pauline Arriaga and many others, to find ways to give students more control over the labs, while introducing them to concepts and skills, such as writing computer code.

To make these lab classes work from home, students needed access to the right tools, which also meant affordable equipment, such as the Arduino UNO Starter kit for Physics 4AL and 4BL and the Snap Circuit Kit for Physics 5CL, which Arisaka and his teaching assistants have been using for a couple of years.

Arduino and Snap Circuit kits provide dozens of basic hardware components that allow those without backgrounds in electronics and programming to create low-cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Students have been able purchase these kits online or the UCLA Store and their wide availability has also made the transition easier.

Students were grouped to work together remotely via Zoom breakout rooms from day one. The highlight of the course was to conduct their group final projects during the last three weeks and present the results by Zoom video-recording. It seems the only limit to students' projects was their imagination.

Projects included: comparing human versus automated coin flips; measuring the effect of music on human reaction time; observing the energy lost by a bouncing ball; predicting the trajectory of basketball shots; comparing use of force across five sports; studying how the shape of a rolling object affects its acceleration as it rolls down an inclined surface and comparing the observations with physics theory.

"Students seem to be enjoying it, and as TAs we enjoy their creativity," said Gowda, graduate student researcher in UCLA's Smart Grid Energy Research Center, who noted that these types of ideas will improve student learning even once in-person instruction resumes. "They develop experiments and projects that we wouldn't even think of."

While previous versions of the class covered the necessary material, said Kramer, their structure seemed antiquated. "The move to this more modern hardware platform, using the coding language Python, and Arduino, has really inspired students to do amazing final projects," he said.

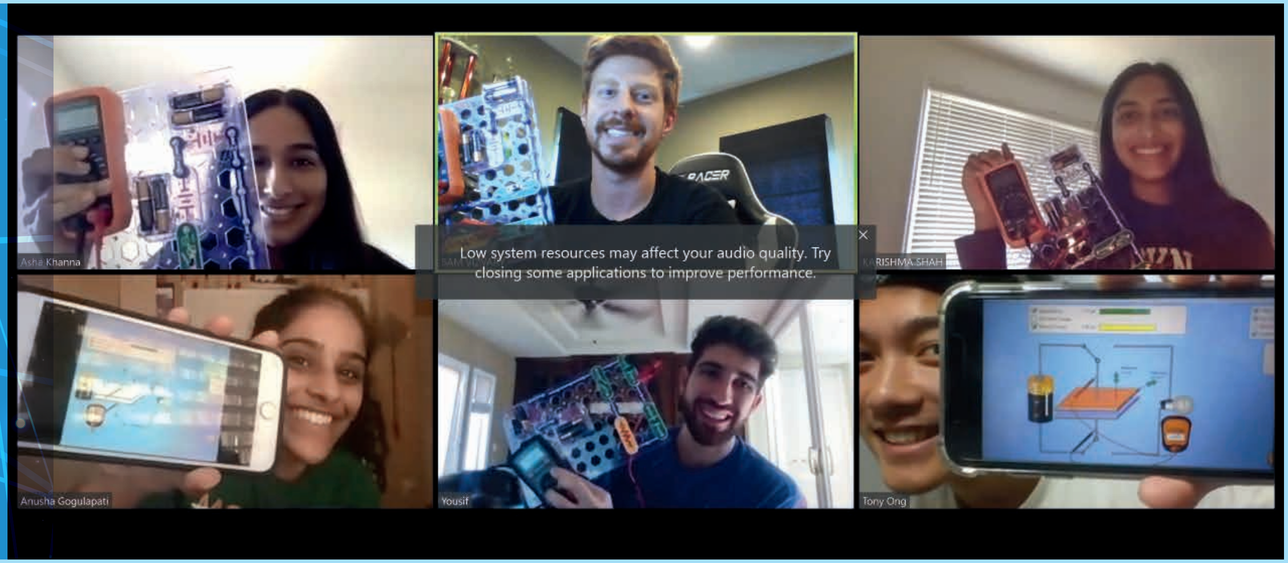
According to Carmona, the way these labs were previously run just didn't capture the imagination of students as much as they should. Speaking on the transition, he says it was a difficult task, but one that was well worth the effort.

"It required a lot of work to get to where it's at, but I'm glad we put in the work because now we have hundreds of students who didn't miss out on a hands-on laboratory they could do at home," Carmona said.

To make the hands-on, labs-at-home work the instructors "flipped" the class, encouraging students to design and test their own experiments rather than making them follow strict guidelines from teaching assistants and professors. Abandoning the old ways for physics labs proved positive according to student responses.

Among the comments from students provided as part of the course feedback: "You all are doing great, by far the most fun class I have this quarter, thank you for all the effort you guys have been putting into this, I figure it's got to be really hard putting together a remote lab, but you guys are doing a pretty dang good job :)" "We are learning marketable skills with Arduino and Python and the course development team is very receptive to feedback

“We are learning marketable skills with Arduino and Python and the course development team is very receptive to feedback and constantly tries to make the class better. Thank you!”



Thanks to off-the-shelf kits, UCLA students studying physics could do their lab work in their homes and design their own experiments. Photo courtesy of Katsushi Arisaka.

and constantly tries to make the class better. Thank you!”

Another change that the group is proud of is asynchronous operation — which allows students to learn at their own pace. This switch has given students flexibility to work at a rate they feel comfortable with, a change that can be beneficial for students who may be struggling with the material.

“The videos demonstrating how to use python and how to set up experiments have been extremely helpful, especially to someone like myself who has no experience with this as I’ve not taken 4AL,” wrote another student.

At the same time, Arisaka said, letting students work at their own pace also allows students who really understand the material to finish their work faster, and he encourages them to go back and help their peers.

Arisaka, who has been teaching physics for more than 30 years, also said it’s time to move away from the notion that students should be competing with one another for grades.

“They can boost their grade if they do better, it has nothing to do with the student next to them, and this message is very important so they can learn something useful,” said Arisaka, who noted that students’ mastery of skills was better than ever this quarter, even though labs were conducted at home.

These changes to the lab structure were possible thanks, in part, to funding and support provided from the UCLA Center for the Advancement of Teaching. “That transition to students having ownership of the experiment is the kind of high-level learning experience that we seek for UCLA students, so we were happy to support that work,” said Adrienne Lavine, associate vice provost for the UCLA Center for the Advancement of Teaching and a professor of mechanical engineering.

For Lavine, the move to remote instruction has created an opportunity for faculty to reflect on their teaching and how that affects student learning. “I think there’s a lot of faculty out there who are doing an incredible job of being thoughtful in how to handle this, and they will learn lessons that can be taken back into in-person instruction,” she said. ●

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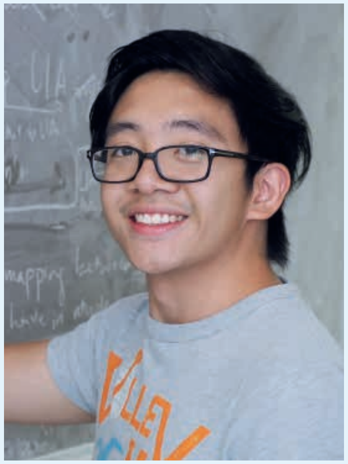
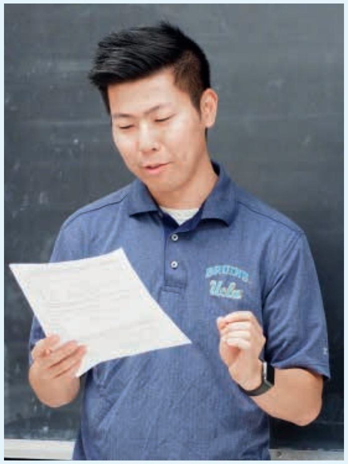
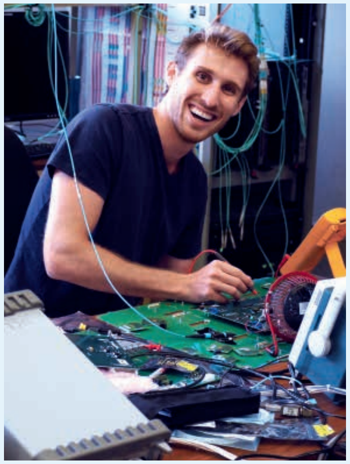



Major gifts have allowed graduate and undergraduate students to spend more time on their research or studying, with a hiatus from the duties of teaching (not necessarily the students shown).

The Matching Gift Program is aimed at significantly transforming the future of UCLA Physical Sciences.

Dean's Gift Matching Funds

UCLA PHYSICAL SCIENCES DEAN Miguel García-Garibay is dedicating resources to inspire others to give through the Physical Sciences Matching Gift Program. This program is aimed at significantly transforming the future of UCLA Physical Sciences through endowed support. We recognize the urgency to address social justice priorities and the critical need to increase the diversity of our faculty, staff and student body. A broader pool of talent fosters greater scientific accomplishments and empowers underrepresented communities that significantly benefit our society. As a commitment to these efforts, gifts in support of diversity, equity and inclusion will be considered at a more significant match.

Diversity, Equity and Inclusion
Qualifying gifts of $100,000 to $1 million to any Physical Sciences endowment aimed at increasing diversity, equity, and inclusion within the division will be matched at 100%.

Other Endowments
Qualifying gifts of $100,000 to $1 million to all other Physical Sciences endowments will be matched at 50%.

If you are interested in learning more about how you can establish your legacy through an endowment that will help ensure the Department of Physics & Astronomy remains one of the top departments in the country for decades to come, please contact Amber Buggs at amberbuggs@support.ucla.edu or (310) 267-5194.

Donors who generously made $5,000+ gifts to the Department of Physics & Astronomy between July 1, 2019 – June 30, 2020

The Ahmanson Foundation
David and Patricia Aires
The American Physical Society
John R. Engel
Heising-Simons Foundation
Amy and Stephen Hogan
Michael and Gretchen Kriss
Arthur Levine and Lauren Leichtman
John and Lauren Liberati
Karla and William MacCary III
Gordon and Betty Moore Foundation
Andrea and Timothy O'Riordan
Planetary Science Institute
Howard and Astrid Preston
Marc Seltzer and Christina Snyder
Robert and Jane Schneider
Ralph and Shirley Shapiro
Alfred P. Sloan Foundation
Stony Brook Foundation, Inc.
Lawrence and Carol Tannas
Michael Thacher and Rhonda Rundle
John and Ann Wagner
W.M. Keck Observatory
Charles and Ying Woo
Dorothy P. Wong


Michael and Gretchen Kriss


John and Lauren Liberati

The Impact of Giving

THIS YEAR the Department of Physics and Astronomy received commitments for several incredibly meaningful endowments: the Michael and Gretchen Kriss Endowed Ph.D. Physics Bridge Program Fund, the Andrea M. Ghez Centennial Term Chair in Astronomy and Astrophysics, and the John and Lauren Liberati Endowed Graduate Fellowship.

Both the Michael and Gretchen Kriss Endowed Ph.D. Physics Bridge Program Fund and the Andrea M. Ghez Centennial Term Chair in Astronomy and Astrophysics furthers the department's goal to thoughtfully strive to increase diversity, inclusion, and equity within physics and astronomy at all levels – from students to faculty. And this year's commitment to add to the existing John and Lauren Liberati Endowed Graduate Fellowship will double the size of this endowment and enable the department to offer one fully funded year of graduate study to each future fellowship recipient of this fund once the pledge is complete. Each of these gifts received Dean's Gift Matching Funds to enhance their impact within the department.

Donor support was critical during the transition to remote learning and teaching

THIS ACADEMIC YEAR relied on the flexibility of the Department of Physics and Astronomy Chair's Discretionary Fund like few times before. In March, our community transitioned quickly to teaching, learning, and researching remotely. While our day-to-day operations were unquestionably interrupted, we remained focused on our students as our first priority in order to keep classes, office hours, and labs going. Discretionary support made it possible for us to have flexible funds that the Chair could quickly allocate to immediate needs to fulfill this priority.

Three important examples of this are:

- Bonus stipends were provided to 77 physics and astronomy TAs to help them address unexpected financial difficulties due to COVID-19. These stipends also recognized the extra work required of them during the ramp up to remote learning.
- Tablets such as iPads were purchased to lend to TAs to enable remote teaching in discussion sections.
- Lab equipment kits were purchased and mailed to our undergraduate students so they could still have a hands-on learning experience at home during the spring quarter.

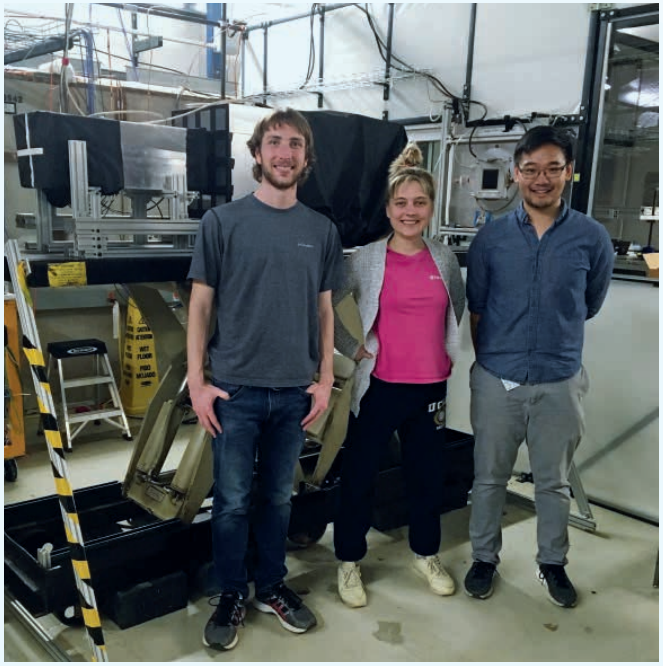
UCLA Experimental Nuclear Physics Group

Prof. Huan Huang

THE UCLA EXPERIMENTAL NUCLEAR PHYSICS GROUP has been a founding member of the STAR and sPHENIX experiments at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). RHIC is a national facility dedicated to the study of Quantum ChromoDynamics (QCD) under extremely high temperature and energy densities and the investigation of the parton structure of the proton.

STAR is the only running experiment at RHIC now, which is in the midst of a beam energy scan to investigate the QCD phase diagram and to search for a possible critical point for nuclear matter.The sPHENIX detector is the next generation of major experiment under construction, and is expected to be ready for commissioning and data-taking by the FY2023 RHIC Run.

The UCLA group is also playing an important role in the STAR upgrade project for a Forward Calorimeter System (FCS), which was designed by the UCLA group. We carried out a successful beam test run of a prototype at FNAL in 2019.



UCLA graduate students Dylan Neff, Maria Sergeeva and Brian Chan, at Fermilab for a beam test of a calorimeter prototype designed by the UCLA nuclear physics group.

In early 2020, the U.S. Department of Energy announced the selection of BNL to host the next national nuclear physics facility, the Electron-Ion Collider (EIC). A new electron acceleration ring will be built in the RHIC tunnel and electron beams will collide with the ion beam from one of the RHIC rings. The plan is to start the construction of the EIC around 2025 and be ready for science at the end of this decade.

The UCLA group developed a new tungsten-powder/scintillating fiber (W/ScFi) spaghetti calorimeter technology with the support of an EIC generic detector R&D program. The detector technology has been adapted for the sPHENIX barrel electromagnetic calorimeter and will be viable for an EIC detector. The UCLA group is a member of the UC EIC Research Consortium supported by the MRPI program from the UC Office of the President.

We are also working on R&D of a calorimeter system for jet measurements at EIC. With the EIC on the horizon, the future of high energy nuclear physics looks very bright.

The UCLA group is playing an important role in the STAR upgrade project for a Forward Calorimeter System, which was designed by the UCLA group.

Prof. Newman was appointed as vice chairman of the American Physical Society's Topical Group on the Physics of Climate (TGPC). Newman will be promoted to Chair Elect and Chair of the group over the next two years.

Many-Body Physics

Prof. William I. Newman

PROF. NEWMAN COMPLETED HIS SABBATICAL YEAR at the Institute for Advanced Study in Princeton, where he focused on the response by charged particles in energetic astrophysical and space-physics environments where magnetic fields undergo turbulent change over very small distances.

Upon his return to UCLA, he resumed extending many-body theory regarding the stability of massive ring-like ensembles in the presence of giant planets in a collaboration with Dr. Philip Sharp from the University of Auckland. Prof. Newman also resumed a collaboration with Dr. Hamid Hajmomenian from UCLA's David Geffen School of Medicine, developing a fluid-flow/physiological model in understand aspects of end stage kidney disease.

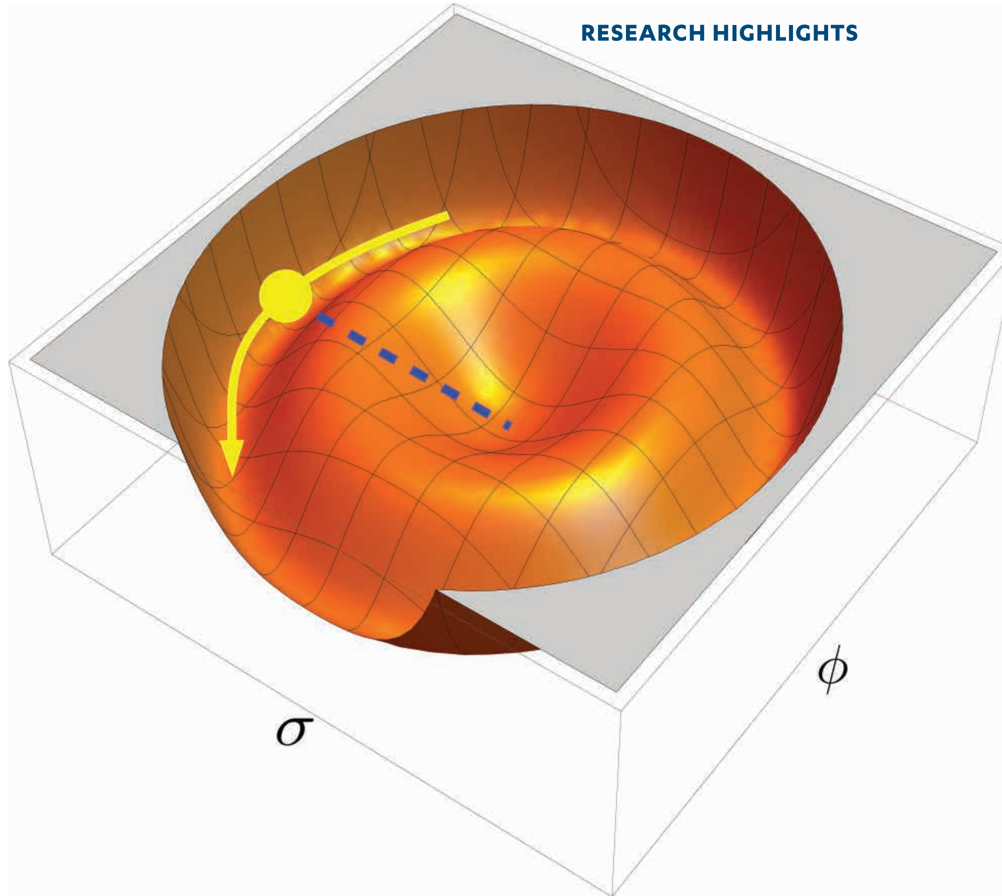
Theory of Elementary Particles, Astroparticle Physics, & Phenomenology

Prof. Alexander Kusenko

PROF. KUSENKO, UCLA postdocs Dr. Volodymyr Takhistov and Dr. Edoardo Vitagliano, and UCLA graduate student Marcos Flores study the nature of dark matter, the origin of matter in the universe, some basic questions about the forces of nature, black holes, and the most energetic astrophysical objects in the universe.

Primordial black holes, which could form in the early universe before the stars were born, can account for all or part of dark matter in the universe, and can explain the population of positrons near the galactic center, as well as synthesis of heavy elements. The early universe is dense enough to produce black holes if the density perturbations are large enough. Kusenko and his collaborators showed that such large perturbations could be generated by scalar fields, which tend to develop large values in the expanding universe.

Just as gravity can cause a cloud of gas to become inhomogeneous and form stars, the scalar forces can cause a similar instability leading to small black holes. Dark matter could be made up of black holes with masses smaller than the Moon. Japanese astronomers have invented a way to search for such primordial black holes using the Subaru telescope, and the first observations have produced an intriguing candidate event. More observations are scheduled for 2020-2021 by an international team that includes Professor Kusenko and several Japanese astronomers.



A scalar field tunneling in this potential in the early universe can produce dark matter in the form of primordial black holes.

Theoretical and Mathematical Physics

Prof. Eric D'Hoker

OVER THE PAST YEAR, PROF. ERIC D'HOKER, in collaboration with Carlos Mafra (Southhampton, England), Boris Pioline (Paris, France) and Oliver Schlotterer (Uppsala, Sweden), succeeded in explicitly constructing the superstring scattering amplitude for five external massless states at two-loop order.

Very few such superstring amplitudes are known but once they are available (as was the case for the four-state amplitude constructed in 2005 by D'Hoker and Phong) they open a wide laboratory for theoretical exploration of S-duality in Type IIB superstring theory and the low energy behavior effective interactions induced on supergravity.

The Department's inaugural Julian Schwinger Graduate Fellowship recipient, Justin Kaidi, contributed brilliantly.

The Department's inaugural Julian Schwinger Graduate Fellowship recipient and D'Hoker's student, Justin Kaidi, contributed brilliantly to the development of one such application, namely modular graph forms. Justin will be a Research Assistant Professor at the Simons Center for Geometry and Physics at Stony Brook starting in Fall 2020.

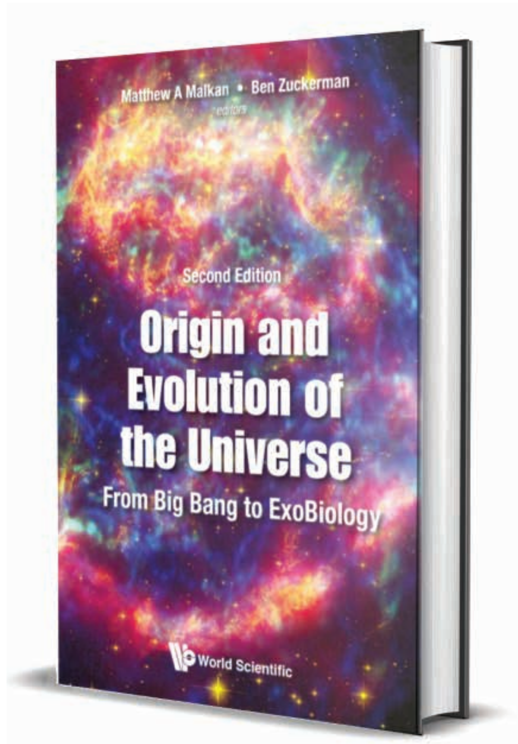
RESEARCH HIGHLIGHTS

Timely Update that Covers the Second Golden Age of Astronomy

Profs. Matthew Malkan & Ben Zuckerman

IN MARCH 1995 BEN ZUCKERMAN AND MATT MALKAN hosted a memorable Symposium at UCLA, on *The Origin and Evolution of the Universe*. It attracted overflow audiences from diverse elements of the Los Angeles community, including students, faculty, researchers, and members of the interested general public. The speakers then prepared and extended their presentations for publication of the First Edition of *The Origin and Evolution of the Universe*. In the subsequent 25 years, the subject has changed so dramatically, that the editors decided it is now high time for a thorough update.

In October, the editors and authors hosted a world-wide Zoom conversation with 200 participants, moderated by Sir Martin Rees, which discussed the questions addressed in the book, the video recording is viewable here: https://youtu.be/d0ST3wvb-R4 .



Front cover above. The back cover includes warm endorsements from 3 recent Nobel Laureates in Physics.

In 1995, supernovae had not yet been used to establish a cosmic distance scale accurate enough to determine that the Universal expansion is — surprisingly — accelerating. The remarkable detection of gravitational waves from merging black holes and neutron stars by LIGO was still decades in the future. And essentially no planets beyond our solar system were known to exist, and certainly none that were anything like our Earth.

Fortunately, for the Second Edition, Malkan and Zuckerman were able to obtain complete updates from six initial contributors, who are active leaders in their scientific specializations. Their topics range broadly, from Chapter 1, on The Big Bang, by our Department's own Professor Edward Wright, to Chapter 6 (on Life in the Universe), by Chris McKay. Chapters 2 through 5 include the latest discoveries about the Origin and Evolution of Galaxies (by Alan Dressler), the Origin of the Elements (by Virginia Trimble), the Evolution and Death of Stars (by Alex Filippenko), and the Birth of Stars and Planetary Systems (by Fred Adams).

The Second Edition is lavishly illustrated with many color images, and a comprehensive Glossary. The book aims to bring lay readers with an interest in science, as well as professional scientists, up to speed on the key discoveries that are part of the panorama of cosmic evolution, which has ultimately lead to our existence on Earth.

For further information about *The Origin and Evolution of the Universe* go to https://www.worldscientific.com/worldscibooks/10.1142/11447.

Problem Solving in Physics

Prof. Josh Samani

PRACTICE MAKES PERFECT, but what kinds of practice are most effective when learning physics? Prof. Josh Samani and his colleague Steven Pan of UCLA's Department of Psychology study how the scheduling of practice over periods of weeks or months influences physics problem solving performance.

Guided by prior laboratory and classroom studies of practice scheduling, Samani uses controlled classroom experiments to investigate how interleaving problems from different subtopics influences the strength and durability of problem solving performance over many weeks. Although prior evidence in the literature on the science of learning supports benefits of interleaving, it has not been previously studied in undergraduate physical sciences classrooms.

Samani's long-term vision is to increasingly engage with researchers from psychology, neuroscience, mathematics, and physics to run longer-term, controlled classroom studies on the optimization of mathematical science practice schedules.

Blocked Problem Schedule									Interleaved Problem Schedule									
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	B_1	3a	A_1							
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	B_2	A_1	3b	A_2	B_1	C_1				
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	A_3	A_1	A_2	B_1	B_3	C_2	C_1	3c	B_2	
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	B_3	B_2	C_2	A_2	A_1	C_3	B_1	C_1	A_3	
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	A_2	B_3	B_2	C_2	C_3	A_1	A_3	B_1	C_1	
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	C_1	A_3	B_3	C_2	A_2	B_1	B_2	C_3	A_1	
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	A_2	A_1	C_2	B_3	A_3	C_3	C_1	B_2	B_1	
A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3	A_3	A_2	C_1	B_2	A_1	A_2	B_3	C_3	C_2	B_1
A_1	A_2	B_1	B_2	C_1	C_2				A_3	A_1	B_3	C_1	A_3	C_3	B_3	C_3	B_2	B_1
A_1	A_2	B_1	B_2	C_1	C_2				B_2	C_2	A_1	C_2	B_1	C_2	A_2	C_1	A_2	B_2

An illustration of how blocked practice, wherein a certain topic is practiced multiple times in succession, differs from interleaved practice during which problems from different topics are shuffled together.

Keeping Our Students Engaged During the COVID Era

Prof. Ben Zuckerman and Dr. Beth Klein

IN ADDITION TO HER VERY ACTIVE RESEARCH PROGRAM, UCLA Astronomer Dr. Beth Klein has found time to lead the formation and development of a diverse, interdisciplinary circle of UCLA undergraduate and graduate students. Our group began before COVID-19, but it has flourished during the past few months when face-to-face contact is not possible. The group is currently composed of four undergraduates (all in Physics & Astronomy), two graduate students (one in P&A and one in the Department of Earth, Planetary, and Space Sciences, or EPSS), Dr. Klein, and Professor Ben Zuckerman. Dr. Klein leads our Zoom meetings that occur about twice a month, each for 60 -90 minutes.

The students are working on research projects in various areas of astronomy. When COVID-19 suddenly prevented our meetings from taking place in the Astronomy Conference Room, we quickly transitioned to using Zoom. During these Zoom meetings the students present/update their research efforts with commentary and questions from the other students. Screen sharing of graphs, images, manuscripts and presentations has enabled us to maintain a high level of scientific productivity. It's not quite as much fun as being together in person, but at least we no longer have to worry about scheduling a time slot in the Conference Room and struggling with the projector.

During summer 2019 one of the undergraduate students participated in our department's REU program; three others participated in the 2020 summer program. The group meetings gave these students an excellent opportunity to improve their final oral REU presentations based on comments from the other students and from Dr. Klein and Prof. Zuckerman. As best we can tell, the participating students really appreciate the chance for safe, informal, interactions with their peers during this time of pandemic.

Dr. Klein has progressed from a UCLA undergraduate Physics major to Physics graduate student to senior researcher in the Astronomy Division. As an undergraduate she worked in the Particle Beam Physics Laboratory. As a graduate student, Dr. Klein became an astronomer, first with the Galactic Center Group and later researching characteristics of planetary systems that orbit white dwarf stars under the guidance of Professor Michael Jura.

Dr. Klein is currently the glue that holds together cooperative research on white dwarfs in our department with Prof. Zuckerman and in the EPSS department where Prof. Edward Young resides. Thanks to Dr. Klein's efforts, UCLA has managed to retain its premiere U.S. position on researching white dwarf planetary systems, notwithstanding Professor Jura's untimely death.

Decoding the Contents of Distant Galaxies with Keck Spectroscopy

Prof. Alice Shapley

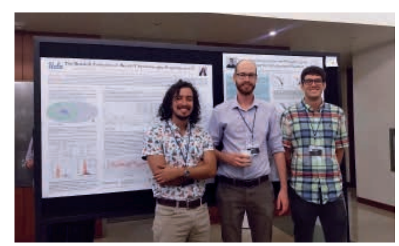
UNDERSTANDING THE FORMATION and evolution of galaxies remains one of the great challenges of modern cosmology. Key outstanding questions include: What are the physical processes driving the formation of stars in individual galaxies? How do galaxies exchange matter and energy with their intergalactic environments? How do the impressive variety of galactic structures that we observe today assemble? How do supermassive black holes affect the evolution of their host galaxies? And how do large-scale structures of galaxies assemble across cosmic time?

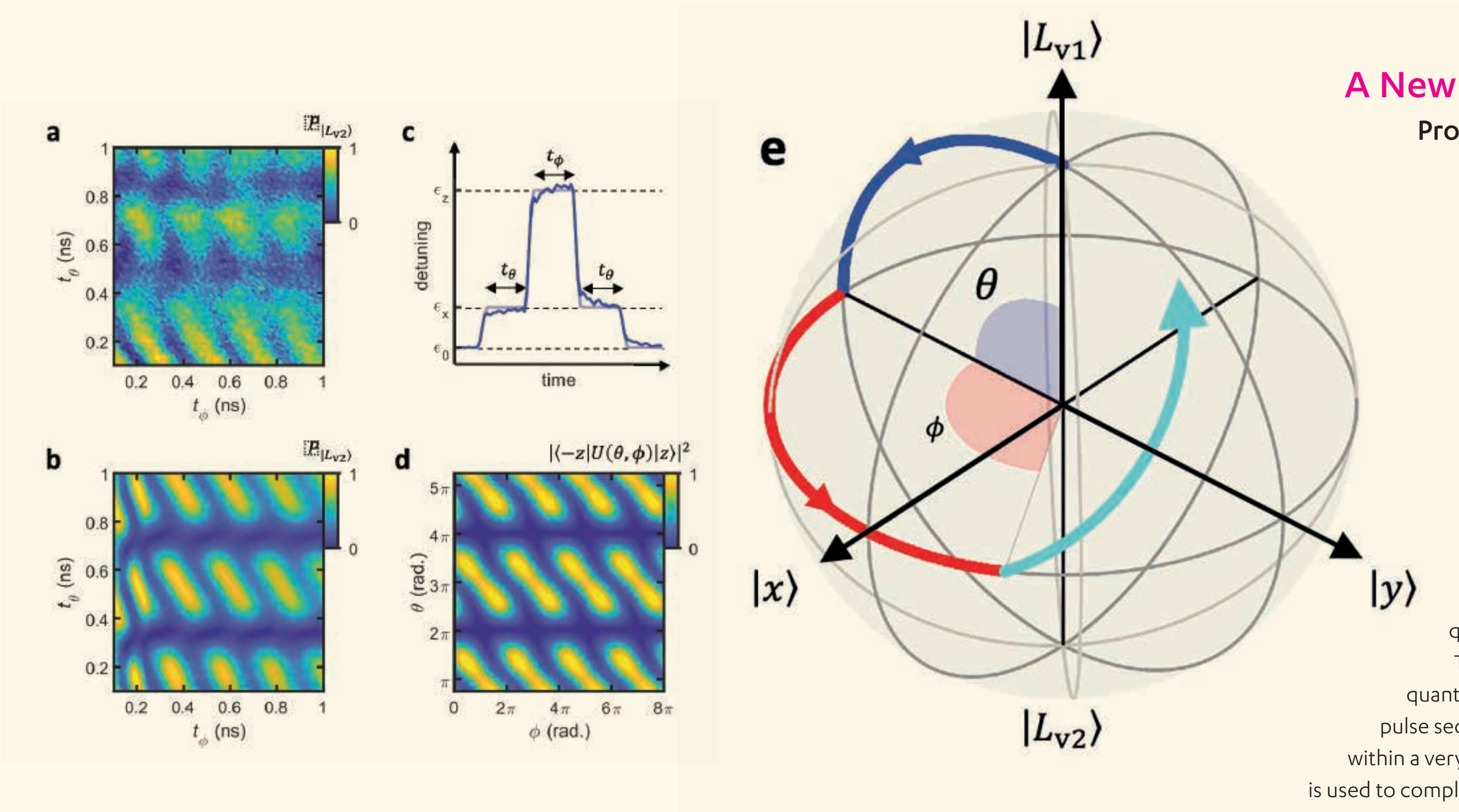
Professor Alice Shapley and her group – Michael Topping, Tony Pahl, and Jordan Runco – use sensitive optical and near-infrared spectroscopic observations at the Keck Observatory to address these questions. Notably, we are frequent users of the MOSFIRE near-infrared spectrograph, built here at UCLA.

We target galaxies forming stars in the early universe, observed as they existed roughly 10 billion years ago. This early epoch was an active time in the history of the universe, when the rate at which stars formed within galaxies was an order of magnitude higher than today, and galaxies looked very different.

One of the essential goals for the Shapley group is to use near-infrared spectroscopic measurements to characterize the evolving heavy element (i.e., oxygen) content of galaxies, which provides important constraints on their growth and assembly. Another key goal is to measure the properties of large-scale gas outflows in distant galaxies using optical (i.e., rest-frame ultraviolet) spectroscopy. The flow of gas into and out of galaxies remains one of the least-understood, yet important components of the galaxy formation process.

From left to right, graduate students Tony Pahl, Michael Topping, and Jordan Runco posing in front of their posters at the 2019 Keck Science Meeting, held at UCLA.





a, b Measured and simulated oscillations with a dynamical projection axis determined by t_θ, demonstrating a complete map of the Bloch sphere surface. Independent oscillations as functions of pulse widths are visible with frequencies of 4.6 GHz and 2.5 GHz. c Pulse form used for two-axis state rotations. Pulse heights are fixed at ϵ_x and ϵ_z and the pulse widths t_θ and t_ϕ are varied. d Theoretical prediction of the measured probability e A schematic of the three pulse stages. In stage 1 (blue), the state is rotated about x by angle θ. In stage 2 (red), the state is rotated about z by angle ϕ, and in stage 3 (cyan) the state is rotated about a tilted axis by angle θ', where θ' = θ by design.

A New Type of Qubit

Prof. HongWen Jiang

QUANTUM DOTS IN SILICON are a promising architecture for semiconductor quantum computing due to a high degree of electric control and compatibility with existing silicon fabrication processes. Although electron charge and spin are prominent methods for encoding the qubit state, valley states in silicon can also store quantum information via valley-orbit coupling with protection against charge noise. Prof. HongWen Jiang's group is developing new type of qubits encoded entirely by the valley quantum states.

This year, the group demonstrated two-axis quantum control of the valley qubit using gated pulse sequences with X and Z rotations occurring within a very fast operation time of 300 ps. This control is used to completely map out the surface of the Bloch

Graduate student Nicholas Penthorn, a Julian Schwinger Fellow of the department, is the lead author of the paper.

sphere in a single phase-space plot that is subsequently used for state and process tomography. This research has been published in *Nature Partner Journal: Quantum Information*. Graduate student Nicholas Penthorn, a Schwinger Fellow of the department, is the lead author of the paper.

The new normal: (left to right) top row: Alexander Stephan, Smadar Naoz, Melodie Sloneker, Huiyi (Cheryl) Wang, Denyz Melchor. Second row: Isabella Trierweiler, William Lake, Yeou Chiou, Juan Pablo Gatica, Shelley Cheng. Third row: Thea Faridani, Isabel Angelo, Eric Zhang, Jesus Salas, Sanaea Rose. Fourth row: Bao-Minh Hoang, Cuc (Cookie) Dinh, Elizabeth (Liz) Holzknecht.

Binaries and Collisions

Prof. Smadar Naoz

THIS YEAR, Alexander Stephan and Yeou Chiou graduated, and we wish them the best of luck in their next step. Research-wise, our group had grappled with socially distant hidden astrophysical friends even before it became fashionable (or at least the way of life). Here are a few highlights.

Does the supermassive black hole at the center of our galaxy, Sgr A*, have a hidden friend?
Almost every galaxy, including our Milky Way, has a supermassive black hole at its heart, with masses of millions to billions of times the mass of the Sun. Since galaxies evolve by merging and colliding with one another, collisions between galaxies will result in supermassive black hole binaries. Using the observations of a well-studied star called S0-2, we compared the predicted effects of a possible supermassive black hole binary on S0-2's orbit. Thus, we placed limits on the possible allowed configuration of such a friend, requiring S0-2 to be on a distant orbit from the black-hole pair.

For example, we can already rule out the idea that there is a second supermassive black hole with mass above 10^5 M_{Sun}, farther than 200 astronomical units. However, a smaller companion black hole can still hide there. Such an object may not alter the orbit of SO-2 in a way we can easily measure.

The danger in breaking social distance
Bao-Ming Hoang in a first-author paper investigated the collision between black holes and neutron stars, emitting gravitational waves at dense stellar clusters. Sanaea Rose in Rose et al. (2020) showed that accumulated gravitational interactions, as well as collisions between distant stars and a binary at the galactic center, could be used to constrain the unseen underlining density. In both cases, breaking social distance has dire consequences.

Thermodynamics and Hydrodynamics

Prof. Christian Fronsdal

CHRISTIAN FRONSDAL, Professor Emeritus since 2019, has been pursuing his work on Thermodynamics and Hydrodynamics. This work has resulted in a new theory of Thermodynamics, solidly formulated as an action principle.

The book *Adiabatic Thermodynamics of Fluids, from Hydrodynamics to General Relativity* was published in September 2020. The new theory of hydrodynamics has led to dramatically successful applications, subjects of recent preprints:

Wind Tunnels: A straightforward application of the theory to the problem of drag on a hard sphere that is placed in a steady wind – a classic problem – has given results in full accord with experiments first carried out by Newton. This is a signal achievement

Metastability of Fluids, Capillarity and Superfluids: The same theory predicts the occurrence of negative pressures in van der Waals fluids. It explains the formation of raindrops and menisci, and it offers a natural explanation of the most dramatic properties of superfluid Helium.

Stability analysis for Cylindrical Couette Flow: Exactly the same theory accounts for experiments on cylindrical Couette flow and offers an interpretation of the breakdown of stability of the lowest flow regime. It predicts, in particular, that the pressure at the inner wall approaches zero at the moment of breakdown, a result that may not have been the subject of experimental verification.

Rotating Planets: An application that predicts the existence of planetary rings (in principle, not yet in any detail) and accounts for the streams observed around the North Pole of Saturn.

Inside the Meniscus. Stresses in compressible fluids: The same theory explains the physics that lies behind the description of the meniscus in terms of surface tension. It also predicts the pressure profile below the meniscus.

Experimental elementary particle physics at the Large Hadron Collider at CERN

Profs. Michalis Bachtis, Robert Cousins, Jay Hauser, and David Saltzberg

Assistant Professor Michalis Bachtis with his Ocean Trigger board for the LHC, based on one of the largest Field Programmable Gate Arrays (FPGA) in existence.

THE COLLIDER PHYSICS GROUP studies the highest energy proton-proton collisions in the world using the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) at the CERN laboratory in Geneva, Switzerland. Having focused on graduate students and postdoctoral scholars in our group in previous years, we focus this year on the untenured faculty, which at present means our sole Assistant Professor, Michail (Michalis) Bachtis.

Prof. Bachtis arrived at UCLA in October 2016 after earning his Bachelor and MSc degrees in Greece, his Ph.D. at the University of Wisconsin-Madison, and working in the CERN Physics Department as a post-doctoral fellow and subsequently a staff physicist. During these years, he made a series of major contributions to the discovery of the Higgs boson, the last piece of the Standard Model of elementary particles to be observed.

The Higgs boson discovery opened the door to a host of searches for new phenomena "beyond" the Standard Model, including searches for heavy new particles that decay to the Higgs boson, or that are made in association with it. Prof. Bachtis and his students, David Hamilton and Tyler Lam, and postdoc, Dr. Simon Regnard, have vigorously pursued several of these possible scenarios, improving the techniques previously used in CMS, and placing constraints on the speculation. This work is supported by the U.S. Department of Energy.

Looking forward, the LHC will dramatically increase the intensity of the beams in order to look for rarer and rarer processes. This poses challenges in many aspects of the experiment, including the real-time selection of about one in 40,000 "snap-shots" of proton-proton collisions that was described as "panning for scientific gold" in the 2017-2018 issue of Reflections. Prof. Bachtis and his graduate students have already upgraded the current CMS trigger by introducing new algorithms in Field Programmable Gate Array (FPGA) firmware extending, the CMS discovery capabilities to regions of the parameter space of new physics not accessible before.

As the consortium of some 50 U.S. institutions in CMS is planning major upgrades to the CMS detector in the next five years, Prof. Bachtis proposed adding new scope to the U.S. trigger hardware responsibilities, and made a convincing case to the collaboration, CERN management, and funding agencies though a long series of reports and reviews. Thus he (and Prof. David Saltzberg, with separate responsibilities) are part of an 18-institution $75 million Major Research Facility Construction (MREFC) project from the National Science Foundation, administered by Cornell University.

Prof. Bachtis' group will design, build, and test 20 processors featuring the largest FPGAs on the market, which will perform real-time selection of charged particles known as muons. A major proof-of-principle was a circuit board he named Ocean. Graduate students Leah Perri, David Hamilton, and Tyler Lam contributed algorithm studies with the upgraded detector; electronics engineer (a UCLA Physics undergraduate alumnus) Maxx Tepper and firmware engineer, Ismael Garcia, contributed to the Ocean design and firmware.

After the approval of this project and two years after joining the project, the CMS experiment acknowledged his contributions to the upgrade and asked him to serve as the Deputy Manager of the hardware trigger system, with the responsibility to manage the whole trigger upgrade effort (U.S. and international) for the next two years. Since the trigger chooses what proton-proton collision events will be available for use in data analysis (which are otherwise thrown away forever), this position requires a broad and deep understanding of the physics capabilities of CMS (both new phenomena and precision measurements of known phenomena), and the wisdom to balance competing priorities.

While the Large Hadron Collider has a rich physics program ahead of us, it is not too soon to start thinking about the future of the energy frontier of particle physics and the next generations of accelerators. UCLA's strong accelerator physics program provides an opportunity to test new ideas and technologies at UCLA that could be used in the energy frontier in the future.

In summer 2020, Prof. Bachtis started working with Prof. Pietro Musumeci on a feasibility study towards using FPGAs for real-time intra-pulse feedback system in linear accelerators. They obtained a donation from Xilinx of a board with an RF chip that is similar to that in the Ocean board, with high speed Analog-to-Digital Converters and Digital-to-Analog Converters. A feedback system will capture in real time the field in the cavity in Prof. Musumeci's Pegasus lab at UCLA. The FPGA then will detect imperfections and generate corrections in real time that are fed back to the RF system. First tests are underway.

Meanwhile, Prof. Bachtis has seized the opportunities for classroom teaching with enthusiasm, in lower and upper division lecture classes and labs. His deep engagement in teaching has been acknowledged by the students in their teaching evaluations, resulting in the P&A department-wide "Teacher of the Year Award" in 2019. He is promoting diversity and inclusion as part of his departmental service in admissions committees and in hires in his research group.

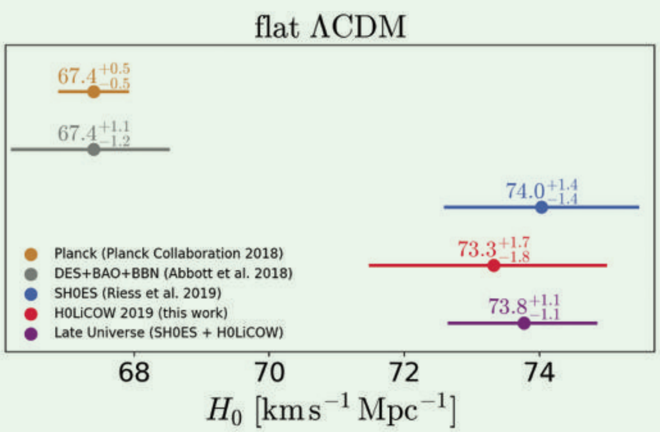
The Universe on Grand Scales

Prof. Tommaso Treu

FOLLOWING UP on their determination of the Hubble constant, and the increasing tension between early and late universe probes, the group has been working improve the overall precision and investigate potential source of systematic uncertainties.

Extraordinary evidence requires extraordinary proof. The group published the largest study to date of the chemical abundance of gas within galaxies ~10 billion years ago. The results are consistent with numerical models of galaxy formation and evolution with strong feedback.

Treu's group received funding from NSF, NASA, and the Moore Foundation. Xuheng Ding started as a postdoc at Kavli Institute for the Physics and Mathematics of the Universe in Tokyo. Daniel Gilman completed his Ph.D. and started a postdoctoral appointment at the University of Toronto. Anowar Shajib completed his Ph.D. and will soon start a postdoctoral position at the University of Chicago. Graduate student Peter Williams received a dissertation year fellowship. Postdoc Guido Roberts-Borsani and graduate students Veronica Dike, Thomas Schmidt, and Lizvette Villafana joined the group. Finally, Prof. Treu published 29 refereed papers.



Comparison of Hubble constant constraints for early-Universe and late-Universe probes in a standard flat LCDM cosmology. The early-Universe probes shown here are from Planck and a combination of clustering and weak lensing data, Baryonic Acoustic Oscillations, and big bang nucleosynthesis. The late-Universe probes shown are the latest results from the local distance ladder and our time delay cosmography work. When combining the late-Universe probes (purple), we find a tension >5 sigma. From Wong et al. (2019).

Correlating 3D atomic defects and electronic properties of 2D materials with picometer precision

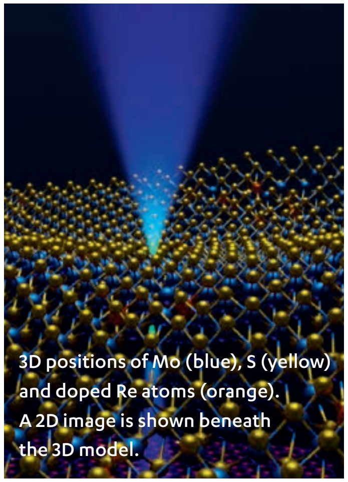
Prof. Jianwei (John) Miao

TWO-DIMENSIONAL (2D) materials and heterostructures exhibit exceptional electronic, optical and chemical properties, promising to find applications ranging from electronics and photovoltaics to quantum information science. However, the exceptional properties of these materials strongly depend on their 3D atomic structure especially crystal defects.

Using Re-doped MoS_2 as a model, Miao and colleagues have recently developed scanning atomic electron tomography (sAET) to determine the atomic positions and crystal defects such as dopants, vacancies and ripples with a 3D precision down to 4 picometers (X. Tian, D. S. Kim et al., *Nature Materials 19*, 867-873 (2020)).

They measured the full 3D strain tensor and quantify local strains induced by single dopants. By directly providing experimental 3D atomic coordinates to density functional theory (DFT), they obtained more truthful electronic band structures than those derived from conventional DFT calculations relying on relaxed 3D atomic models, which was confirmed by photoluminescence spectra measurements. Furthermore, they observed that the local strain induced by atomic defects along the z-axis is larger than that along the x- and y-axis and thus more strongly affects the electronic property of the 2D material.

It is expected that sAET is not only generally applicable to the determination of the 3D atomic coordinates of 2D materials, heterostructures and thin films, but also could transform ab initio calculations by using experimental atomic coordinates as direct input to reveal more realistic physical, material, chemical, and electronic properties. This paper is published.



3D positions of Mo (blue), S (yellow) and doped Re atoms (orange). A 2D image is shown beneath the 3D model.

Attosecond coherent diffractive imaging

Attosecond science has been transforming our understanding of electron dynamics in atoms, molecules and solids. However, to date almost all of the attoscience experiments have been based on spectroscopic measurements because attosecond pulses have intrinsically very broad spectra due to the uncertainty principle and are incompatible with conventional imaging systems.

Recently, Miao and colleagues have reported a major advance towards achieving attosecond coherent diffractive imaging (A. Rana, J. Zhang et al., Phys. Rev. Lett. 125, 086101 (2020), in press). Using simulated attosecond pulses, they simultaneously reconstructed the spectrum, 17 probes and 17 spectral images of extended objects from a set of diffraction patterns. They further confirmed the principle and feasibility of this method by successfully performing a coherent diffractive imaging experiment using a light-emitting diode with a broad spectrum. This work potentially clears the way to an important unexplored domain of attosecond imaging science, which could have a far-reaching impact across different disciplines.

One of the most exciting aspects of the G objects is that the gas that gets stripped off of them by tidal gravitational forces as they swing by the central black hole must inevitably fall into the black hole. When that happens, it might produce an impressive fireworks show, since the material eaten by the black hole will heat up and emit copious radiation before it disappears across the event horizon. (Image Credit: Jack Ciurlo)

Galactic Center Group

Profs. Andrea Ghez, Mark Morris, Eric Becklin, Tuan Do, and Research Astronomer Shoko Sakai

THE MISSION OF THE UCLA GALACTIC CENTER GROUP (GCG) is to transform our understanding of black holes and their role in the evolution of galaxies with high-resolution observations of the center of our galaxy. The center of the Milky Way is the closest example of a galactic nucleus in the Universe and is the only one that can be studied through the measurement of stellar orbits, providing a unique laboratory for studying the fundamental physics and astrophysics of black holes and their environs.

Galactic Center Group celebrates 25th Anniversary

The UCLA GCG launched its signature program – the Galactic Center Orbits Initiative (GCOI) – 25 years ago. When the first set of images that initiated the GCOI was taken on June 10, 1995 at Keck Observatory, the team consisted of only four people. Since then, over 100 students, postdocs, faculty, researchers, and observatory staff have worked on the wide range of scientific discoveries that have emerged from GCOI. This program is still going strong and has become a key science case for the development of instrumentation at W. M. Keck Observatory and the future Thirty Meter Telescope.

To celebrate the success, the GCG is hosting a number of activities this year, beginning with a reunion of the scientific team. Although we could not meet in person, we were able to celebrate with a Zoom party on June 9th with alums and collaborators from around the world. Many of us shared stories which highlighted various stages of GCOI: speckle imaging at Keck from the '90s; discovering a supermassive black hole (SMBH) at the Galactic Center; launch of Adaptive optics (AO); obtaining spectra of Galactic Center (GC) stars and finding young stars where no young stars were expected; seeing the black hole brighten suddenly as it accretes matter. We also looked forward to the next 25 years!

While we didn't go to Hawaii, we were able to use the new "pajama mode"...

SCIENCE HIGHLIGHTS

A population of dust-enshrouded objects orbiting the Galactic black hole. The GC is also home to a cluster of young massive stars and gas clouds. A study headed by UCLA postdoc Anna Ciurlo, Prof. Mark Morris and Keck Observatory scientist Randy Campbell discovered a larger population of the unusual objects, called G sources, that have been found to be orbiting the SMBH. These objects look like gas and behave like stars; they look compact most of the time and stretch out when their orbits bring them closest to the black hole. The first of this class of objects, named G1, was identified by Prof. Ghez in 2005. The GCG team believes that these much-debated sources are most likely the products of two stars that had been orbiting the black hole and driven, by the central black hole, to merge (through the three-body Kozai-Lidov interaction) into an extremely large star cloaked in a thick envelope of gas and dust. This new discovery was published in Nature this January and picked up by media around the world.

These objects look like gas and behave like stars; they look compact most of the time and stretch out when their orbits bring them closest to the black hole.

Search for Variation of the Fine structure constant around a Supermassive Black Hole. Searching for space-time variations of the constants of Nature is a promising way to uncover new physics beyond general relativity and the standard model, motivated by unification theories and models of dark matter and dark energy. A study led by Prof. Tuan Do and Dr. Aurelien Hees, which was published in Physical Review Letters, used GCOI spectroscopic measurements to search for variations of the fine-structure constant. A measurement of the difference between distinct absorption lines (with different sensitivity to the fine structure constant) from a star leads to a direct estimate of a variation of the fine structure constant between the star's location and Earth. Our measurement, which constrained the relative variation to less than 1 part in 10^5, is the first time the fine-structure constant has been carefully measured in the deep gravitational potential around a black hole.

Two newly-minted GCG Ph.D.s
GCG training of students continues at full-speed during the pandemic. This summer two graduate students successfully defended their theses becoming Dr. Abhimat Gautam and Dr. Devin Chu.

Dr. Gautam used over 13 years of Keck Observatory AO GCOI imaging data to precisely monitor the photometric flux (the brightness) of the stars within a light year of the central SMBH. To do this, he analyzed the data on much shorter timescales than used for the orbits analysis, revealing the presence of binaries through their eclipses. One of the most exciting results from this work is his discovery of the first example of an ellipsoidal, giant binary system (stars that are so close that they are tidally distorting each other) at the GC. This is ironically the softest binary star system detected to date at the GC (~80 day period) and its existence allows the application of a novel method to measure how many stellar-mass black holes or neutron stars there are close to the central SMBH.

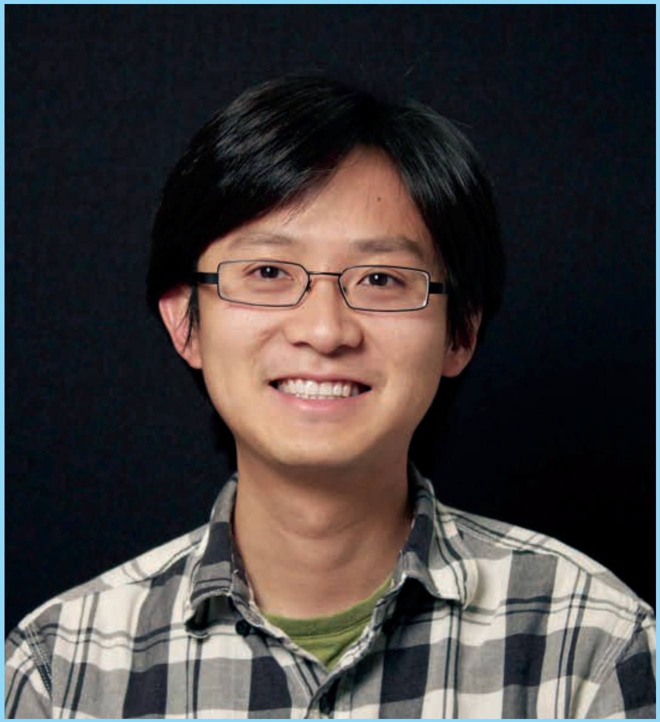
In a complementary study, using the GCOI spectroscopic data set, Dr. Chu conducted the first systematic search for spectroscopic binaries in the GC to investigate the formation mechanism of the young stars located closest to the SMBH, which remains a mystery. Results suggest that these stars are single stars, placing limits on the intrinsic binary fraction of these stars. This limit on the binary fraction for early-type stars disagrees with the binary fraction of similar type of stars in the solar neighborhood and by more than some merger theories support. This contrasts our eclipsing binary star search at larger radii and provides insight into the so-called "paradox of youth" (how can these young stars exist so close to the black hole?). A possible explanation that would produce a reduction in the binary star fraction is that the early-type stars closest to the black hole may be produced through the Hills mechanism.

The two newest graduates of the GCG Abhimat Gautam (left) and Devin Chu (right).

Zooming to the Center of the Galaxy!
Keck Observatory was closed at the beginning of the pandemic, but, fortunately, it reopened in late May 2020, saving the 2020 Galactic Center observing season for us. While we didn't go to Hawaii, we were able to use the new "pajama mode", which allowed us to connect to the observatory and control the instrumentation from home. It is a brave new world for doing Astronomy & Astrophysics research!

Paulo Alves

Paulo Alves joined the department's pioneering and preeminent plasma group in November 2020. Prof. Alves works in the theory and computational modeling of laboratory and astrophysical plasmas. His work also includes the development of tailored machine learning algorithms to advance theoretical understanding and accelerate computational modeling of complex plasma dynamics. He received his doctorate in Portugal at the Instituto Superior Tecnico of the University of Lisbon. Prof. Alves was recently a research associate at the SLAC National Accelerator Laboratory run by the Department of Energy and Stanford University.



Tuan Do

Tuan Do joined our department faculty in July 2020. Just prior to that, he was an Associate Research Scientist and Deputy Director of the Galactic Center Group, and will continue as Deputy Director of the Galactic Center Group. Prof. Do received his Bachelor's degree from UC Berkeley and Ph.D. from UCLA. His research interest is in understanding the formation of the nuclei of galaxies. He is currently studying the composition and star formation history of the Milky Way nuclear star cluster and how these stars interact with the supermassive black hole at the Galactic center. He is also interested in leveraging the potential of machine learning to aid scientific discoveries as the amount and complexity of astronomical data are growing exponentially.

Christopher Gutiérrez

Christopher Gutiérrez joined the Hard Condensed Matter Physics group in July 2020. Before joining UCLA, Prof. Gutiérrez was a Prize Postdoctoral Fellow at the Quantum Matter Institute at The University of British Columbia and a Postdoctoral Fellow at the National Institute of Standards and Technology (NIST). His research combines atomic-scale imaging and photoemission spectroscopy techniques in the study and design of novel states of matter in low-dimensional quantum materials. Prof. Gutiérrez earned his doctoral degree in physics from Columbia University, his master degree in physics from California State University, Los Angeles and his undergraduate degrees in physics and mathematics from UCLA.

"In addition to the world-class research atmosphere, UCLA provides me the opportunity to make a difference in my hometown," Gutiérrez said. "I grew up in South Central Los Angeles and am a first-generation American and college graduate. It's a dream come true to now be in position to be an advocate and mentor for the many talented students from our under-served communities." ●

Mikhail Solon

Mikhail Solon joined our department in July 2020. His work includes precise theoretical calculations based on quantum field theory relevant to experiments in dark matter detection, cosmology, and gravitational waves. Prof. Solon is winner of the 2015 J.J. and Noriko Sakurai Dissertation Award in Theoretical Particle Physics from the American Physical Society. Recently he was the McCone Fellow at the Walter Burke Institute for Theoretical Physics at Caltech. From 2014 to 2017, he was a postdoctoral scholar at the University of California at Berkeley and the Lawrence Berkeley National Lab. He looks forward to 2021 when he can meet all of you on campus. ●

Above (from left to right): Warren Mori, Christoph Niemann, Smadar Naoz, Ni Ni, and Edward (Ned) Wright

PROF. WARREN MORI won the 2020 James Clerk Maxwell Prize for Plasma Physics of the American Physical Society.

"For leadership in and pioneering contributions to the theory and kinetic simulations of non-linear processes in plasma-based acceleration, and relativistically intense laser and beam plasma interactions."

PROF. CHRISTOPH NIEMANN won the 2020 APS John Dawson Award for Excellence in Plasma Physics.

"For generating Weibel-mediated collisionless shocks in the laboratory, impacting a broad range of energetic astrophysical scenarios, plasma physics, and experiments using high energy and high power lasers conducted at basic plasma science facilities."

This national award is named after UCLA's late **PROF. JOHN DAWSON** one of the luminaries of computational plasma physics and the inventor of laser-plasma acceleration.

PROF. SMADAR NAOZ won the 2020 Helen B. Warner Prize of the American Astronomical Society (AAS) for "for her many early career contributions to theoretical astrophysics, especially her influential and creative studies in cosmology and dynamics."

The citation reads, "She has provided important insights into the behavior of radiation and matter after cosmological recombination and the formation of the first stars, and she has devised compelling explanations of the unexpected orbital properties of hot Jupiters. Her work on the dynamics of hierarchical triple systems has been applied to many other fields of astronomy, including stars and binary supermassive black holes, giving us crucial insights into the events detected by the Laser Interferometer Gravitational-wave Observatory (LIGO)."

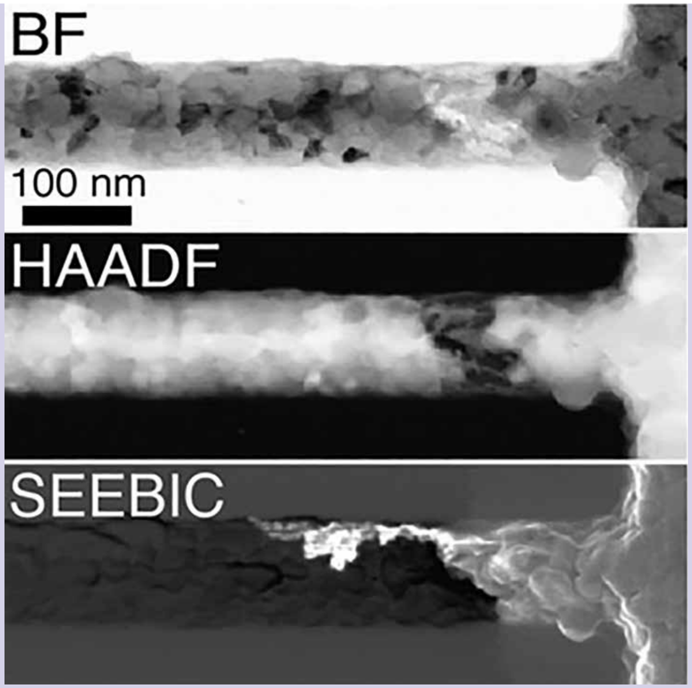
PROFS. NI NI and **EDWARD (NED) WRIGHT** were named by Web of Science as the world's most influential researchers of the past decade, demonstrated by the production of multiple highly-cited papers that rank in the top 1% by citations for field and year in Web of Science.

PROFS. IAN MCLEAN and **ANDREA GHEZ** were named inaugural fellows of the American Astronomical Society (AAS) "for their contributions toward the AAS mission of enhancing and sharing humanity's scientific understanding of the universe."

PROFS. ANDREA GHEZ and **ERIC HUDSON** were named Fellows of the American Physical Society.

PROF. ZHONGBO KANG won the NSF CAREER Award, one of the foundations most prestigious awards given to early-career faculty, for his proposal "Hadron's Transverse Structure and Associated QCD Dynamics".

PROF. THOMAS DUMITRESCU was named a UCLA Hellman Fellow. These awards were established by the Hellman Family Foundation "to support and encourage the research of promising Assistant Professors who show capacity for great distinction in their research."



PROF. ALICE SHAPLEY gave the prestigious Kavli Foundation Plenary Lecture at the national meeting of the American Astronomical Society (AAS) in Summer 2019. Her lecture was entitled *Key Outstanding Questions in Galaxy Formation and How to Answer Them*. This lecture is "a special invited lecturer to kick off each semiannual AAS meeting with a presentation on recent research of great importance."

PROF. CHRIS REGAN and **DR. WILLIAM HUBBARD** won the 2019 Microscopy Today Innovation Award.

PROF. ERIK PETIGURA won a Sloan Research Fellowship, which selects early-career scientists and scholars who are rising stars of science.

Left: Alice Shapley

Right: Regan and Hubbard's award-winning paper contrasts traditional bright field (BF) and high-angle annular dark field (HAADF) scanning transmission electron microscopy (STEM) with their new secondary electron electron-beam-induced-current (SEEBIC) imaging technique.

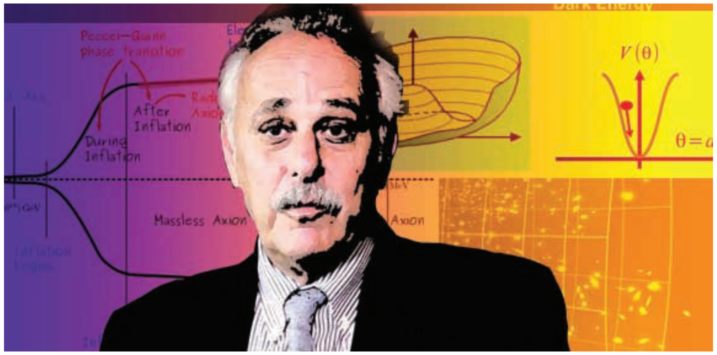
Starting in 2020 the UCLA Physical Sciences Division gave awards for the most important aspects of our mission. Physics & Astronomy won many of these awards.

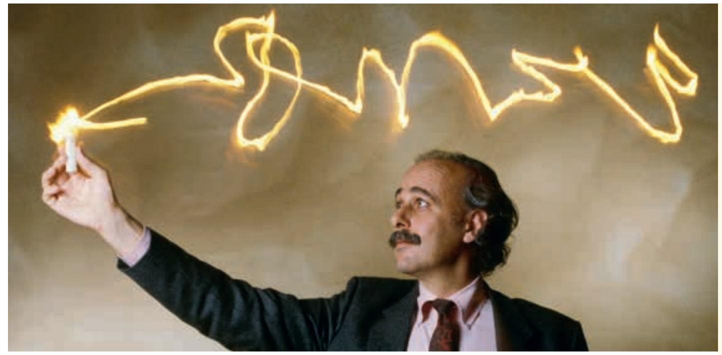
PROF. TOMMASO TREU won the Centennial Research Award for "the greatest research discovery made by a Physical Sciences faculty member and their team in 2018-2019." He made an important measurement of the Hubble constant, discovering a tension among techniques that could indicate new physics.

PROF. STUART BROWN won the Centennial Mentorship Award, for a faculty member who "has demonstrated a commitment to and success in mentoring research students from diverse backgrounds" and "establishes and nurtures inclusion, and inspires creativity, perseverance and other positive qualities that have led students to leadership positions in industry, government and academia."

Alumnus **DR. HOWARD PRESTON** (B.S. 65, Ph.D. 74) won the Centennial Luminary Award, given to alumni "in recognition of their professional accomplishments."

Project Scientist and post-doctoral alumnus **DR. MANI BHAUMIK** won the Centennial Visionary Award "to recognize one individual who has made extraordinary contributions through their service to UCLA and whose career exemplifies the impact of research and education across several areas of the Division of Physical Sciences."





Roberto Peccei

ROBERTO PECCEI (1942-2020) was a brilliant scientist, a natural leader, a thoughtful colleague, and a special friend. During his distinguished career at UCLA, he served as department chair (1989-93), dean of Physical Sciences (1993-2001), and vice chancellor for research (2000-10), overseeing a significant expansion of UCLA research efforts and the advent of major institutes.

Peccei was born in Torino, Italy in 1942. He was a son of Aurelio Peccei, an Italian industrialist and philanthropist, who was a member of the anti-fascist movement and the resistance during World War 2.

Peccei completed his secondary education in Argentina. He obtained a BS from MIT (1962), MS from NYU (1964) and PhD from MIT (1969). After a postdoctoral position at Univ. of Washington he held a faculty position at Stanford and later the Max Planck Inst. in Munich, Germany. He later became head of the theory group at the large European laboratory, DESY.

One of the most famous scientific contributions, and an example of Peccei's brilliant thinking is the celebrated Peccei-Quinn symmetry, proposed in collaboration with Helen Quinn. Interactions of elementary particles, as well as the very existence of matter in the universe depend on how different the world would be under the hypothetical action of flipping all particle charges and reflecting the world in a mirror. This mathematical transformation, called "CP" is closely related to flipping the arrow of time.

Peccei's seminal and groundbreaking contributions have been recognized by numerous prizes and awards. He was particularly happy to receive the J.J. Sakurai Prize for Theoretical Particle Physics awarded by the American Physical Society, of which he was a long-standing member and a fellow as well as chair of its Division of Particles and Fields. Peccei was also elected a fellow of American Association for the Advancement of Science and a fellow of Institute of Physics, UK. He was awarded the order of Commendatore in Italy. He served on the Executive Committee of the Club or Rome

He was a passionate communicator of science, who enjoyed teaching graduate and undergraduate students at UCLA. In recent years, his course on the Physics of Energy served as a source of much needed knowledge and inspiration for his students and colleagues. The memory of Roberto Peccei will continue to inspire his colleagues, postdocs and students. ●

His course on the Physics of Energy served as a source of much needed knowledge and inspiration...

William "Bill" Slater

PROF. WILLIAM (BILL) SLATER passed away on July 14, 2019. He spent most of his career as one of the pioneering members of the UCLA experimental high-energy physics group.

After receiving his Ph.D. (1958) from the University of Chicago, Bill became a professor at UCLA in 1962. He contributed to the foundations of particle physics, including determining the quantum numbers of the phi meson, now known to be the first bound state of two strange quarks. These were found to agree with predictions by the famous UCLA theoretician J. J. Sakurai.

Bill's decades of work included experiments with colliding electrons, K mesons, and the highest-energy particles ever observed — cosmic rays with energies in excess of 10^{20} electron-volts. Bill was equally at home with both detector hardware and analysis software.

He nominally retired in 2006, but continued to be a daily presence in the department, continuing his active research program, being recalled to teaching, and always improving the Physics 180F particle-physics undergraduate laboratory. Bill's wife Marilyn has told us how much he loved the department. ●

At this Women+ in the Physical Sciences (WPS) Club meeting, incoming students and sophomores ask the more advanced students questions about academics, social life, clubs, and more at this social event hosted in the PAB. (Pictured: Sara Alkidim, Jena Shields, Elizabeth Castro, and Daphne Chen)

The graduate-student-led planetarium hosted over 2,600 attendees before campus shut down due to the pandemic. In addition to the free weekly shows open to the public, private shows were given to 25 educational groups from the Los Angeles area. The Planetarium continues to play a major role in Exploring Your Universe, the High School Summer Program, and the general education course Astronomy 3. The UCLA Planetarium is hosting virtual planetarium shows during the pandemic period, with over 1,700 attendees tuning in for a single show. These virtual public shows are happening monthly, and also stay up for asynchronous viewing on the UCLA Planetarium YouTube channel.

The Astronomy Live! Program held outreach events for five public elementary schools in Winter 2020 before the public health crisis required us to suspend all in person activities. We hosted four of these events at UCLA, and visited one school that could not make the trip out to campus. These outreach events consisted of fun and educational science demonstrations such as water bottle rockets, gravity demonstrations, mobile planetarium presentations, and pocket solar system demonstrations. Astronomy Live! Is providing virtual demonstrations for elementary schools during the global pandemic period.

Science Lab Teaching Club

Science Lab Teaching Club (SLTC) is an outreach club that goes to schools around UCLA area to teach kids physics. We show demos from the physics department demo lab to school-age kids to enrich their science education. During the 19-20 school year, we visited the 3rd to 5th graders at Brentwood Science Magnet School on two separate occasions to talk about phases of matter and energy, respectively. We also visited kids at various grade levels at Fairburn Avenue Elementary School on five different occasions to do a science day demonstration, talk about various weather-related phenomena, and demonstrate topics such as electricity, magnetism, motion, and states of matter. In Fall 2019, we continued our tradition of attending the annual EYU event by setting up a station for electricity and magnetism demonstrations. Additionally, SLTC realizes its role in promoting a sense of belonging for UCLA students. We attracted many first-year members by attending last year's Enormous Activity Fair. We hope SLTC continues to be a community where students may find each other outside of academics.

Brentwood Science Magnet School visit on Oct 15, 2019. From left to right, Abdulelah Alkhamis, Victoria Zheng, Parth Bhatnagar, Anna Koleva.

EXPLORING YOUR UNIVERSE

On November 3, 2019 we hosted the twelfth annual Exploring Your Universe (EYU) open house. This free event included talks, demonstrations, exhibits, and hands-on activities from the Departments of Physics and Astronomy, Earth Planetary and Space Sciences, Atmospheric and Oceanic Sciences, Chemistry, and Engineering and Applied Sciences, as well as the Center for Environmental Implications of Nanotechnology. Thousands of visitors attended from all over the Los Angeles area.

Prof. Andrea Ghez was awarded the 2020 Nobel Prize in Physics for discovering the Black Hole at the center of the Milky Way Galaxy.

More details will be featured in our AY20-21 annual report next fall!

Photo by Elena Zhukova

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Physics & Astronomy

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The Astronomical Society

The Undergraduate Astronomical Society reorganized into The Astronomical Society to better reflect the diverse participation in the club, which now includes graduate students and staff. Before the pandemic, the Society welcomed hundreds of people to our telescopes each week to explore the skies. People came from all over campus and all over the greater Los Angeles area to see planets, stars, and distant nebulae. The club also met each week to discuss current events in astronomy and help new or novice astronomers get started with using telescopes. Once the pandemic arrived, the Society transitioned to virtual events where we continued to keep up with astronomy and enjoy the new images provided by our group's own astrophotographers. The Society is continuing to hold virtual meetings and virtual stargazing to keep astronomy enthusiasts from UCLA and Los Angeles connected to each other and to the cosmos.