STANFORD PHYSICS

DEPARTMENT ANNUAL NEWSLETTER - 2023/24

The 2023 Physics Summer Undergraduate Research Program- see page 8 for details.

A MESSAGE FROM THE CHAIR

Dear Friends of the Physics Department,

Our annual newsletter is back, after a pandemic-inspired pause. I hope you will find the new format and the material interesting and, maybe, they will motivate you to dig a bit deeper into what is happening in our department.

I have lots of new and exciting topics to report on! Several new colleagues have joined us in recent times: Prof. Susan Clark studies magnetic fields in the interstellar medium, as you will discover reading her piece here. Prof. Ben Feldman is a condensed matter experimentalist, interested in studying emergent quantum electronic states in materials of reduced dimensionality. He also develops new tools to investigate them and managed to start a new laboratory at Stanford during the pandemic. Prof. Jonathan Simon was lured to Stanford (along with Prof. David Schuster in Applied Physics) from the University of Chicago and is setting up extensive laboratories in the Varian building to start an experimental program in quantum devices. Jon and his program are central components of the new Q-FARM initiative that was developed by the university to bolster activities in the area of quantum science and technology, across different departments and schools. Finally, the most recent addition to the faculty is Prof. Trithep Devakul, who is a condensed matter theorist, starting this quarter in our department.

We are also happy to have “back” from administration a number of senior colleagues: Prof. Peter Michelson is back full-time in the department after a stint as Sr. Associate Dean for the Sciences and Profs. Persis Drell and Kathryn Moler will also come back to research and teaching, after their times as Provost and Dean of Research, respectively. Recognizing the need for development in the area of teaching staff, the department recently hired Drs. Charles Blakemore as a Lecturer and Felicia Tam as Physics Education Specialist. Both are also alumni, as Charles received a PhD from our department in 2021 and Felicia was a Physics major here (class of 2002). These new members of the team come on board as George Yan and Rick Pam have retired, after helping teach physics to many generations of students.

There have also been several changes in the administrative staff of the department. Lancy Nazaroff started in March 2023 as our new DFO, replacing Rosenna Yau, who retired after many years of university service. Jenifer Conan-Tice and Cindy Mendel also retired and were replaced by Eldridge Thomas and Maria Frank, respectively. Maria’s move, in turn, resulted in the hire of Nick Swan to run student services. Eunice Han has also joined the student services team. Saira Shah is a new administrative associate, and Dorrene Ross has moved from HEPL to Physics as facilities manager.

It is also appropriate here to remember Prof. Stan Wojcicki who passed away in the spring. Stan had been a member of the physics faculty since 1966 and was twice department Chair. A memorial and a scientific symposium in his honor will be held on Nov. 9-10th.

I invite you to visit us, meet many colleagues leading the respective fields of physics and explore the many new exciting initiatives in the areas of research and instruction.

Giorgio Gratta, Department Chair

FALL COLLOQUIUM 2023

Tuesdays 3:30pm, Hewlett 201

10/3/2023 Giorgio Gratta & Ian Fisher
10/10/2023 Mike Crommie, UC Berkeley
10/17/2023 Jeongwan Haah, Microsoft
10/24/2023 Vladan Vuletic, MIT
10/31/2023 Chris Laumann, Boston University
11/7/2023 Adam Kaufman, CU Boulder
11/14/2023 Yangyang Cheng, Yale Law School
11/28/2023 Peter Abbamonte, University of Illinois – Urbana Champaign (UIUC)

THE STANLEY WOJCICKI MEMORIAL SERVICE AND SCIENTIFIC SYMPOSIUM

11/9/2023 Memorial Service at Stanford Memorial Church. Reception to follow at the Faculty Club
11/10/2023 Scientific Symposium at the Stanford Alumni Center

Alumni Reunion Homecoming - October 20, 5:30 pm - Varian Courtyard
Annual Bill Fairbank Memorial Run/Walk/Bike - Winter Quarter, date TBA
Bunyan Lecture - Winter Quarter, date TBA
Robert Hofstadter Memorial Lecture - Spring Quarter, date TBA

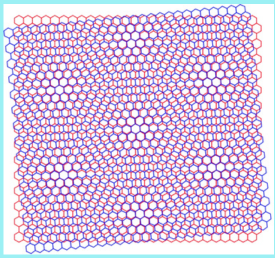
FULL EVENT DETAILS AND MORE AT: PHYSICS.STANFORD.EDU.

NEW FACULTY: TRITHEP DEVAKUL

Hello Stanford! I am delighted to be introducing myself as the newest faculty member in the condensed matter theory group here at Stanford. I am so excited to become a part of the vibrant physics community here.

I spent my childhood in Thailand before crossing the globe to do my bachelor's degree at Northeastern University. I knew from early on that I wanted to do physics, and specifically condensed matter physics: I was just fascinated by how so much of the world around us, like a simple bar magnet, arises from the collective behavior of quantum particles acting in harmony.

I spent a couple years working in an experimental lab, before taking the leap and doing a summer project in theory. The rest is history. I fell in love with the field: it was the perfect mix of fundamental and applied physics. Plus, the field is so incredibly broad and diverse that I could never get bored of it. I went on to do my PhD at Princeton, a postdoc at MIT, and now Stanford. My general research interests lie in exploring all the exotic states of matter that can arise in quantum systems.



Of all the things I've worked on, what I am the most excited about in the coming years is the field of moiré materials. These are a relatively new class of 2D systems formed by taking two or more atomically thin materials, like graphene, and stacking them on top of each other with a small twist. The mismatch between the atomic lattices of the two layers generates a long-period interference pattern known as a moiré pattern (see figure). Electrons moving in the material see the moiré pattern, and the result is that they effectively behave as if they are in a magnified "artificial crystal" (typical moiré periods are =5-10 nm, much larger than inter-atomic distances of 0.1 nm).

I find these systems so interesting because they force us to reconsider the way we think about electrons in materials. In most materials, the kinetic energy of the electron is dominant, and other aspects can often be treated as small corrections. This is inverted here: the moiré lattice works to suppress the kinetic energy, thus enabling other aspects, in particular electron-electron interactions, to take center stage. Studying the physics of such strongly interacting systems is a hard problem at the cutting edge of condensed matter physics.

The physics here mirrors that of the "quantum Hall" regime, where kinetic energy is suppressed by the application of a strong magnetic field. This setting has historically been a stage for breakthrough discoveries, such as the fractional quantum Hall effect famously solved by Laughlin's wavefunction. What makes moiré materials so compelling is their ability to reproduce many aspects of this setting without any external magnetic field. Furthermore, they are an entirely unique material platform with their own set of tuning knobs. I believe we have only begun to explore the potential of these systems and am eagerly looking forward to seeing where the field will go in the next few years.

I feel truly fortunate to be coming to Stanford at this exciting time. I can't wait to begin building my own research group and interacting with the Stanford physics community. I am equally excited to begin my teaching journey here – I will be teaching Physics 111 this fall and look forward to engaging with the next generation of physicists!

2023 FACULTY AWARDS AND HONORS

Benjamin Franklin NextGen Award - Monika Schleier-Smith
For groundbreaking research elucidating fundamental properties of matter and energy by using ultracold atoms and their interactions with light.

Dirac Medal - Stephen Shenker & Leonard Susskind
Shenker and Susskind (with Banks and Fischler) developed the first non-perturbative formulation of M-theory and string theory by providing a limiting procedure that describes the S-matrix.

TOPTICA BEC Award for Lifetime Achievements - Alexander Fetter
For foundational theory works on quantum many-body physics and superfluidity of ultracold gases.

American Academy of Arts & Sciences - Risa Wechsler
For scientific contributions and leadership of large programs in cosmology and large scale structure to resolve the nature of dark matter and energy. The Academy is an honorary society that recognizes and celebrates the excellence of its members.

Faculty Women's Forum Outstanding Leader Award - Risa Wechsler
For an outstanding record of developing a culture of inclusion and promotion of women faculty.

Deborah Rhode Lifetime Achievement Award - Persis Drell & Kathryn Moler
Named after an amazing and fierce advocate for gender equity in the academy, this award honors Professor Rhode's legacy by recognizing individuals who have dedicated their careers and used their influence to advance the status of academic women at Stanford. Given by the Faculty Women's Forum.

Lars Onsager Lecture Medal - Roger Blandford
For his work on black holes. The Onsager Medal (Onsagermedaljen) is a scholastic presentation awarded to researchers in one or more subject areas of chemistry, physics or mathematics.

NEW FACULTY: JON SIMON

I joined the physics faculty at Stanford after a decade at the University of Chicago. My group specializes in quantum control of light, focusing in particular on developing tools to (1) collect, trap & manipulate photons, and (2) entangle the photons by coordinating their absorption by -- and re-emission from -- atoms. I collaborate closely with David Schuster, both in electric-skateboarding & drone piloting, and through our groups, in exploration of quantum science.

Among the various directions that this exploration of light has taken me, I have focused on making matter from light and using it as a platform to study how quantum mechanics impacts the properties of materials. Photons are a rather strange thing to make matter out of, as they do not interact with one another as electrons do, nor do they respond to forces by changing their speed (that is, they have no mass). My group has developed tools to make photon traps (resonators) that imbue the photons with properties that behave like mass, charge & coupling to magnetic fields, and with the ability to collide with one another through coupling to highly excited "Rydberg" atoms and superconducting circuits. This journey has led to the first crystals made of light, the first topological molecule made of light, and the first strongly correlated fluids of light. My team is now exploring ways to leverage entanglement to directly extract properties of these exotic quantum states through manybody interference effects (what they call "Manybody Ramsey Interferometry").

Beyond making quantum matter out of light, I'm fascinated by the challenges associated with development of next-generation quantum hardware: there are a variety of advanced quantum computing platforms coming online today, from arrays of atoms individually trapped in laser beams to ions, to superconducting circuits. These platforms share substantial quantum coherence (the ability to preserve entanglement for long periods of time without being "observed" by the outside world) and strong interactions (the ability to generate entanglement). The analogy to the development of the transistor would suggest that industrial partners should take it from here, "scaling up" these proof-of-concept demonstrations. The reality is that entanglement and the objects that preserve it are so delicate that "scaling" is actually a fundamental-science- rather than systems-engineering- challenge. My group is developing tools to more efficiently measure large quantum systems using arrays of optical cavities and even new approaches to interconvert quantum information between platforms where it is easy to manipulate and platforms where it is easy to transmit over long distances. The variety of technical challenges intrinsic to these problems now transcend the technical capabilities of the Simon & Schuster collaboration, resulting in three-way-efforts with the Safavi-Naeini lab who specialize in nanophotonics and quantum sensing.

I'm also the director of Q-FARM, a cat enthusiast, and a mediocre chess player. I've been working with research groups around physics & applied physics to develop laser-cut lab logos to put on lab doors (what I call "art"); if you have ideas for your lab door definitely reach out to me.

THE STUFF BETWEEN THE STARS
BY SUSAN CLARK

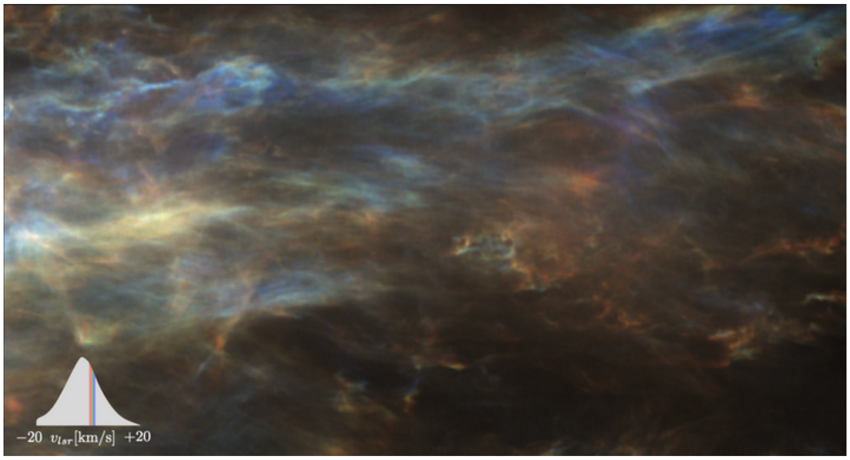


Figure 1: This image shows atomic hydrogen emission from the interstellar medium of the Milky Way. We measure emission as a function of Doppler-shifted velocity, and this three-color image is made by mapping the emission in three adjacent velocity bins to the red, green, and blue components of the image. This figure was adapted from Clark et al. 2019.

Assistant Professor Susan Clark is an astrophysicist, with primary research interests in cosmic magnetic fields, magnetohydrodynamic processes, and the interstellar medium.

When you think of a galaxy like our Milky Way, you might think of a massive knot of dark matter, or of the stars that can be seen splashed across the sky on a dark night. But galaxies are also swirling cauldrons of gas and dust: the material that makes up the interstellar medium, or what you might colloquially call the "stuff between the stars".

The interstellar medium is turbulent and permeated by magnetic fields. It is the material out of which new stars form, and into which some old stars explode. Understanding the flow of matter and energy in the interstellar medium is part of the modern astrophysical quest to understand star formation, the evolution of galaxies, and ultimately our cosmic origins.

Gas in the interstellar medium spans an enormous range of physical states, from hot, diffuse plasma to the cold and dense molecular clouds that are the birthplaces of new stars. We seek to understand the distribution of this material, and the physics that governs flows of gas and transitions between interstellar phases. These are formidable challenges that we undertake from our single vantage point: a smallish, rocky planet some eight kiloparsecs from the center of the Milky Way. The Cosmic Magnetism and Interstellar Physics Group at Stanford is leading the way, working to elucidate the physics of the diffuse and magnetic universe using theory, simulations, and vast quantities of data.

From our little corner of the cosmos, we decipher our gaseous galactic home by collecting light from across the electromagnetic spectrum. One particularly useful window that we have on our universe is line emission from atomic hydrogen. Atomic hydrogen is abundant in galaxies and has a hyperfine transition that corresponds to a photon with a wavelength of 21 centimeters. We observe this "21-cm line" with radio telescopes, measuring both emission and absorption as a function of frequency, or equivalently, Doppler-shifted velocity. Figure 1 shows a region of this 21-cm emission from the nearby interstellar medium.

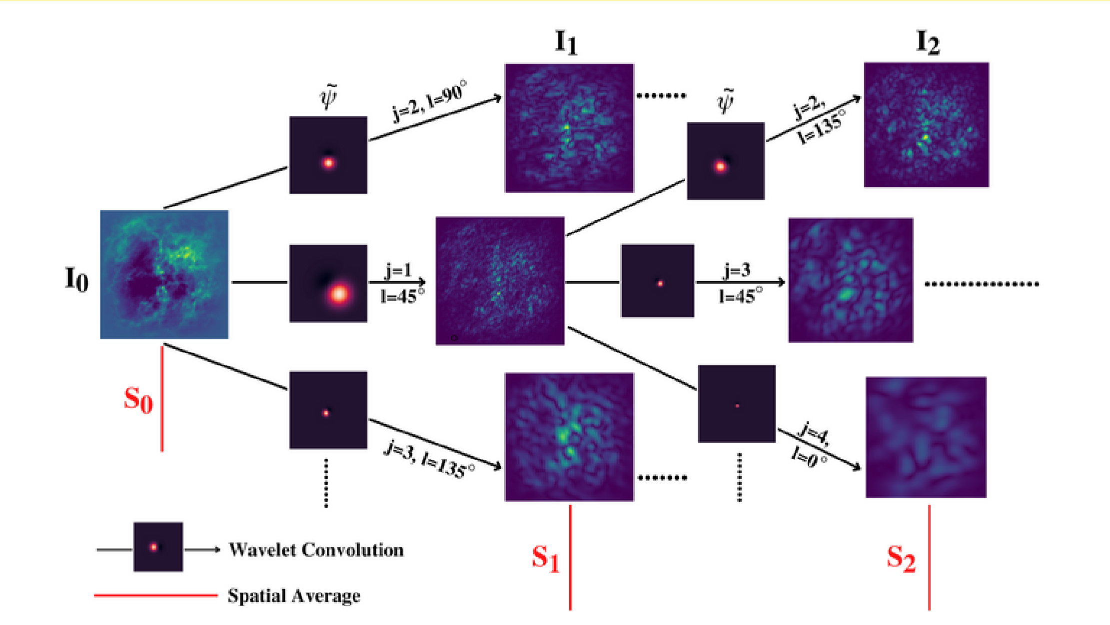


Figure 2: The architecture of the scattering transform as applied to images of atomic hydrogen emission. This figure from Lei & Clark 2023.

Recently, our group has been pursuing new probes of the physical properties of this gas. The neutral medium traced by atomic hydrogen emission is thermally bistable, meaning that there are two stable thermal phases with very different densities and temperatures that coexist at typical interstellar pressures. We call these the "cold neutral medium" and the "warm neutral medium". The cold neutral medium has typical temperatures ~50-100 K, with densities of tens of atoms per cubic centimeter near the Sun. The warm neutral medium is comparatively tenuous, with less than an atom per cubic centimeter and typical temperatures ~6000 - 10,000 K.

Directly constraining the thermodynamic properties of this gas requires both emission and absorption measurements – and absorption measurements require a bright background radio source, like a quasar, against which we can detect interstellar absorption. However, our group has found a promising new avenue: we have shown that substantial physical information is encoded in the spatial distribution of the gas. In other words, we can use clever computational image analysis tools to probe interstellar medium physics directly from hyperspectral data like that illustrated in Figure 1.

Recently, graduate student Minjie Lei led work that quantified the spatial distribution of 21-cm emission with the scattering transform, a statistical technique that originated in the mathematics literature and draws inspiration from the structure of convolutional neural nets, but requires no training (Figure 2). By applying this transform to images of atomic hydrogen emission and comparing to absorption-line measurements, we discovered a link between the morphology of the interstellar gas and its thermodynamic state. This points to exciting new directions for studying the phases of the interstellar medium from emission data alone.

Our group has also discovered connections between gas morphology and the interstellar magnetic field structure. This is an exciting time for our group and for the field, as we find creative new approaches for the analysis of vast troves of astrophysical data. We are designing new algorithms that allow us to quantify image-space morphology in gas and dust emission– and finally probing the rich physics that is etched into the beautiful complexity of the interstellar medium.

IN MEMORIAM: STANLEY WOJCICKI

Stanley G. Wojcicki died on May 31, 2023, at his condo in Los Altos at age 86. He still maintained his home on the Stanford campus.

Stan was an experimental particle physicist who in the 1960s took part in the explosive phase of the field, when many new particles were discovered and the structure of the Standard Model of elementary particles was established. In much more recent times, Stan played an essential role in modern neutrino oscillation experiments using high energy beams.

Photo courtesy of the Wojcicki family.

Born Stanislaw Jerzy Wojcicki in 1937 in Warsaw, Poland, Stan came to the US at age 13 with his mother and brother, fleeing the communist takeover of Poland. He received an AB from Harvard in 1957 and a PhD in physics from UC Berkeley, remaining associated with the Lawrence Radiation Laboratory from 1961 until 1974. In the same period, he also held visiting positions at CERN (Geneva) and College de France (Paris). This was the time when particle accelerators produced copious amounts of new particles, which were then interpreted as excited states of combinations of quarks. Stan was right in the middle of this, using large bubble chambers and electronic detectors.
In 1966 Stan joined the physics department at Stanford as an assistant professor, "probably the best experimental high energy physicist of his age group in the country," as one recommendation letter stated. Among other things, he then started a long love story with Kaons, particles made of two quarks, including one of the "strange" variety. The study of their properties eventually led him to a series of experiments at Brookhaven National Laboratory on Long Island, further consolidating our understanding of the Standard Model.

After more stints at CERN, Stan returned to Stanford as a full professor, serving as department chair from 1982 to 1985. He then became interested in the design of the Superconducting Supercollider (SSC) and took a substantial period of leave to cross the Bay back to Berkeley, where he was deputy director of the "Central Design Group" (of the SSC). On that subject he professed being "very optimistic" but added, "I have learned long ago not to assume that any government action will occur until it actually happens." That was, unfortunately, a prescient thought, and when the SSC was finally canceled by Congress in 1993, Stan devoted the rest of his scientific career to the study of neutrinos. The experiment he led, MINOS, was based on a beam of neutrinos produced by an accelerator at Fermilab, in Batavia, Illinois, traveling about 1000 km underground, and being detected by a large apparatus assembled in a decommissioned iron mine in Minnesota. MINOS was one of the experiments that verified the phenomenon of neutrino oscillations, revealing, among other things, that neutrinos have a finite, albeit minuscule, mass. Stan was physics department chair a second time, from 2004 to 2007.

Throughout his career in physics and academia, Stan was known for his unassuming and warm personality. He was both a great physicist and a wise leader.

Stan met his wife Esther Hochman at UC Berkeley at the University Students' Cooperative Dorm, Sherman Hall, where he was a boarder and she was a resident. They originally connected because he spoke Polish and some Russian and she spoke Russian and was taking Russian classes, so she practiced with him. They loved riding on his Vespa motor scooter all over the Bay Area since they had no access to a car. They married in Berkeley in 1961, just after Esther got her BA degree and just prior to his PhD.

In 1966, they moved to Stanford and in 1968 their first daughter, Susan, was born. Two other daughters followed: Janet in 1970 and Anne in 1973. Stan loved being a father and spent time helping to teach his daughters to play soccer and coaching their AYSO soccer teams. They also were swimmers and he spent countless hours and summers at Stanford Campus Recreation Center cheering them on. He also loved traveling and the family took many trips to Europe, Australia, New Zealand, South Africa and Southeast Asia. He took each daughter on a special trip: Susan to hike in Hawaii, Janet to Brazil, and Anne to Poland.

He taught them the importance of independent thinking, not being afraid to tell things as they are, and sticking to a project no matter how hard it was. He was an exceptionally disciplined athlete and ran every morning for miles even when he was traveling. He only slowed down in his 80s when he was no longer able to run and later walk. He was disciplined about everything in life, and it served him and his family well.

He was very proud of his daughters and their chosen professions: Susan as CEO of YouTube, Janet as professor of pediatrics at UCSF Medical School and Anne as founder and CEO of 23andMe. He was also proud of his wife and her Media Arts Program that she founded at Palo Alto High School and her best-selling book "How to Raise Successful People". He often joked about how they had swapped roles: He used to travel the world talking about physics, and now she was traveling the world talking about education.

He was also proud of his ten grandchildren, who range in age from 4 to 23, the oldest of whom just graduated from Stan's alma mater, Harvard, in computer science in June of 2023. One of his grandchildren, a granddaughter, is now a sophomore at Stanford studying biology. Another of his grandsons will be studying math at UC Berkeley, and a fourth will be studying math at Harvard. The love that Stan felt for math and the sciences has been handed down to the next generation, which brought him joy.

HAPPY RETIREMENT TO:

SHAMIT KACHRU

Professor Kachru is now working with PDT Partners, and his current scientific research is focused on understanding dynamics of various liquid global financial markets.

Previous research interests included diverse topics in theoretical physics, ranging from string theory and quantum gravity to cosmology, condensed matter theory and biophysics.

CARL WIEMAN

Nobel Prize winner Carl Wieman held a joint appointment as Professor of Physics and of the Graduate School of Education. He has done extensive experimental research in atomic and optical physics. His current intellectual focus is now on undergraduate physics and science education. He has pioneered the use of experimental techniques to evaluate the effectiveness of various teaching strategies for physics and other sciences, and served as Associate Director for Science in the White House Office of Science and Technology Policy.

RICK PAM

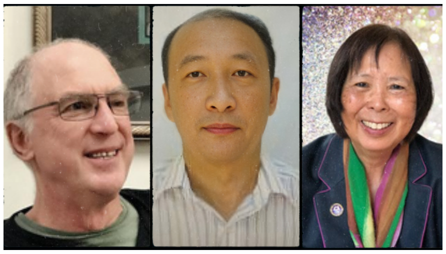
For 30 years, Rick has served as lecturer and teaching lab manager in the advanced teaching labs, Academic Director of the Physics Undergraduate Summer Research Program, advisor to the Society of Physics Students, pre-major advisor, and mentor to undergraduates and graduate teaching assistants.

Prior to his time at Stanford, Rick's work in the fields of chemical kinetics, air pollutant formation and control, and solar thermal power generation led to the development and commercialization of low polluting combustion systems, as well as advanced energy systems, for which he holds two patents. He also taught courses at San Francisco State University, the Illinois Institute of Technology and Hartnell Community College. Rick received a B.S. in Physics and an M.S. in Mechanical Engineering from Stanford.

GEORGE YAN

George served as lab manager for over 30 years, taking care of lecture demos. His courses were taken by an average of 800 students every quarter.

He was a lecturer/associate professor in China for five years prior to getting his Ph.D. at Stanford under the Nobel Laureate, Professor Arthur Schawlow.



ROSENNA YAU

Rosenna served as Director of Finance and Operations from 1991-2023.

By the Numbers...

5 - Nobel Prizes won by Stanford Physics faculty during Rosenna's tenure
27 - Bunyan lectures held
31 - Commencements staffed by Rosenna
31 - Annual Bill Fairbank Memorial Run/Walk/Bikes staffed by Rosenna
379 - Physics degrees earned by women during Rosenna's tenure

You can make a contribution to The Physics Postdoc Fund on behalf of Rosenna.

GIVE.STANFORD.EDU/HONOR/ROSENNA-YAU-RETIREMENT

GIVING TO PHYSICS

PLEASE MAKE A CONTRIBUTION TO THE STANFORD PHYSICS DEPARTMENT AT: **GIVING.STANFORD.EDU**

Donations may also be made by enclosing:

1. A check payable to "Stanford University – Department of Physics" and
2. Specific instructions for the gift in the memo if applicable (eg. to which fund you wish to contribute) and mailing them to:

Department Of Physics
Attn: DFO
382 Via Pueblo Mall
Stanford, CA 94305

FULL EVENT DETAILS AND MORE AT: PHYSICS.STANFORD.EDU.

HIGHLIGHTS FROM THE 2023 PHYSICS SUMMER UNDERGRADUATE RESEARCH PROGRAM

The Physics department has a long history of hosting a robust Summer Undergraduate Research Program involving groups in Physics, Applied Physics, SLAC, and other related departments. This summer, about 50 undergraduate students participated in the 10-week program, conducting research in a broad variety of fields ranging from cosmology to quantum information science. Among the participants, about 40% had just completed their first year at Stanford and were engaging in their first research experience. In addition to Stanford students, we integrated participants from other universities through the Leadership Alliance and Cal-Bridge programs, which are targeted at students from traditionally underrepresented groups.

Students matched with faculty mentors and identified a research topic over the winter quarter, and typically also worked closely with graduate student and postdoc mentors during the summer. In addition to these traditional research activities, students attended weekly faculty seminars and professional development workshops led by graduate student coordinators Cady van Assendelft and Sauviz Alaei. Topics ranged from goal-setting in order to set expectations and priorities at the start of the summer, to a panel involving graduate students representing a breadth of physics subfields, to principles of scientific communication. Undergraduate researchers also had opportunities to attend tours at SLAC and the Student Observatory. Finally, they made time to bond socially as well over physics movie nights, liquid nitrogen ice cream, and a trip to see "Oppenheimer."

The summer research program culminated with students giving 6-minute talks to their peers and mentors, highlighting their accomplishments over the summer. The presentations were excellent; they generally included impressive results and demonstrated awareness of how the work fit into a broader context in the field. We anticipate that in several cases, the summer research will provide a foundation for continued work and thesis research during the upcoming academic school year.

-On behalf of the summer research coordinators: Ben Feldman, Chaya Nanavati, Eunice Han, and Elva Carbajal

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