UC SANTA BARBARA

Kavli Institute for Theoretical Physics

Newsletter

www.kitp.ucsb.edu
Fall 2021

CARTER HIYAMA

Lars Bildsten

KITP is back! The action shot above shows scientists back with us and interacting in the outdoor setting of the newly-named Gurley Courtyard in Kohn Hall. It's been a long haul since March 2020, when we pivoted to all-online programming. I thank all of KITP's staff and our scientific community for their remarkable work and resilience over the last 18 months of uncertainty and change. Now let's see what nature brings next!

We re-opened Kohn Hall for in-person programs in July 2021 (see story on page 2) and have been ramping up operations at the Munger Residence as our visitors return. We have been inhibited from reaching full capacity due to the US travel ban, but that looks likely to change after the ban lifts on November 8, 2021. Even then, we will continue to provide Zoom access to all of our program and conference activities, as we have found this to be an important way to broaden participation in our activities. We've also been busy planning for the future, and have programs organized through Summer 2023.

Fall always marks the time of transitions for KITP's postdoctoral scholars, and three departed this fall. Anna Keselman (Condensed Matter) is now a junior faculty member at the Technion in Haifa, Israel, Nir Mandelker (Astrophysics) is a junior faculty member at the Hebrew University of Jerusalem, and Tianci Zhou (Condensed Matter) is a postdoctoral scholar at MIT's Center for Theoretical Physics. We have eleven new postdoctoral scholars this academic year. In astrophysics, we have Jennifer Barnes from Columbia University, Rocio Kiman from CUNY, and Javier Roulet from Princeton. In high energy physics we have Xizhi Han from Stanford and Ying Zhao from the Institute for Advanced Study, while in condensed matter we have Shang Liu from Harvard, Izabella Lovas from Technical University of Munich, and Ryan Thorngren from Harvard. We have three new biophysicists, Fridtjof Brauns from LMU Munich, Wenping Cui from Boston College, and Sarah Kostinski from Tel Aviv University.

Our postdocs remained productive and impactful during the pandemic, writing about 3 papers each, two-thirds of them with collaborators independent of their KITP and UCSB mentors. They gave an average of 5 scientific talks last year (all on Zoom, of course) and mentored UCSB students, reaching eight undergraduates and over fifteen graduate students. The scientific breadth of their research is remarkable, from studying morphogenesis in animals, to the structure of cold, dense filaments of gas in galaxies, quantum gravity and the nature of entanglement in quantum circuits. You can read on page 3 how May Gade Pedersen and her collaborators used the observed oscillation periods of massive stars from the Kepler telescope to better unravel the levels of mixing within them.

The back page has the inspiring story of a new research thread created by UCSB Physics Emeritus Professor Ray Sawyer. Ray was one of the famous "Gang of Four" who wrote the originating proposal to the National Science Foundation that established the ITP. Thank you to Ray and your colleagues for launching such an exciting endeavor.

About 20 years ago, KITP's then Director David Gross initiated our engagement with local artists to ensure that Kohn Hall would always have a vibrant visual atmosphere. The story on pages 6 and 7 gives an excellent overview of this long-standing artistic engagement. David, at the same time, initiated the transformative effort to identify funds for KITP that are outside of our federal support. This effort caused the re-naming of the institute in honor of Fred Kavli, and, over time, a large growth in support from philanthropists and scientific foundations across the country. This rise of scientific philanthropy has led to a more stable future for the institute, and is now openly celebrated with the naming of spaces in Kohn Hall and the Munger Residence displayed on pages 4 and 5.

As part of this donor and support recognition effort, led by our Senior Director of Development Kristi Newton, we also took the opportunity to document the purpose of KITP. A sentence in one of our new plaques captures the essence of KITP: "The institute's intellectual environment-- both physical and virtual -- enhances discovery through collaboration and the exploration and promotion of new areas of scientific study." It's a wonderful institution to lead and I look forward to whatever comes next.

- Lars Bildsten, KITP Director

Return to In-Person at KITP

Every summer, KITP hosts a quantitative biology program and school. This year, the program happened in person with remote participation. Funded by the Gordon and Betty Moore Foundation, it kicked off in July 2021 as the first on-site event the institute has held since the pandemic began. The school, supported by the Kavli Foundation, ran fully remotely every morning, a successful model that also enabled those in Europe to benefit from the engagement.

MOXI, THE WOLF MUSEUM OF EXPLORATION + INNOVATION

KITP Special Programs and Evaluation Manager, Maggie Sherriffs

"The program coordinators and the participants arrived with a lot of enthusiasm and energy," said Maggie Sherriffs, KITP's special programs and evaluation manager. "I think they were excited to be part of this experiment with us."

The institute was at the forefront of campus reopening, and their approach provides a peek at what may come. In compliance with UC policy, KITP is accommodating only fully vaccinated visitors in Kohn Hall and the Munger Physics Residence, where many of the visiting scientists and their families live.

KITP faculty and staff worked alongside program coordinators to devise innovative solutions to continue hosting researchers during the pandemic, as their mission revolves around bringing together experts for programs. This involved lots of experimentation with streaming presentations, creating digital workspaces and fostering informal discussions.

KITP's leadership intends to incorporate what was learned from this experience into their standard operations. KITP will include remote participation in all of its in-person events going forward; the current activities are the first test-case. It's also an important time for remote participants, as many from outside the United States are unable to enter the country due to COVID travel restrictions.

Programs always have more applicants than Kohn Hall can accommodate, so many had to be turned away in years past with a 'sorry letter.' "We're not going to send those letters anymore," said KITP Director Lars Bildsten "Now we're going to send them a letter saying: 'You are welcome to join as a remote participant.'" Remote participants can view talks, ask questions and contribute to chats. Every program will also make use of digital workspaces such as Slack.

These changes will greatly expand the number of researchers the institute can include in its events, ultimately fostering more scientific collaboration. It will also be a boon for visiting researchers who may not be able to stay for the entire duration of a program. "We want to keep the great things about the in-person KITP experience intact, but also allow people who can't come to participate," said Sherriffs.

Naturally, things will be different than when everyone was remote. "We don't want to disrupt the in-person experience," said Deputy Director Mark Bowick. Visiting researchers have access to workspaces in Kohn Hall, participate in on-site events and engage in casual conversations in Kohn Hall's Gurley Courtyard and the outdoor areas of the Munger Physics Residence that remote participants will not be privy to.

That said, each program will have a unique character set by the community involved, as KITP learned over the pandemic. For instance, researchers at the first in-person program wanted to see their colleagues on Zoom during presentations. "They wanted to try their best to have the people outside on the same footing as the people inside. It has worked rather well," Bildsten said.

Many different modes of collaboration emerged while events were digital: real-time features like recording presentations as well as asynchronous aspects like chatrooms. "You could view the in-person component as yet another mode of working," Bowick said, "one of many possible ways of experiencing a program."

The pandemic and a 10,000-gallon flood in March 2020 provided an opportunity to renovate Kohn Hall with accessibility and remote participation in mind. In addition to repairing about a quarter of the building, the institute incorporated new technology to facilitate hybrid programs. High quality cameras were added to the auditorium and large and small seminar rooms. The facilities also now boast audio loops in the auditorium and main seminar room for the hearing impaired. These consist of induction coils installed below the carpeting that send signals directly from the speaker's microphone to the telecoil in the hearing aids of attendees in the room.

There will also be more hardware available for remote teaching. "It used to be a barrier to coming that you had to teach your class," Bildsten said. "Now, faculty know how to teach remotely, so they can come to KITP and teach their class from here."

The renovation also presented an opportunity to begin transitioning Kohn Hall to LED lighting, part of a broader effort on campus. The kitchen received updates, and the building's public spaces have new carpet. Work has even commenced on reupholstering some of the institute's well-worn furniture!

~ Harrison Tasoff, Science Writer, UCSB Public Affairs

KITP

The KITP quantitative biology program "Ecology and the Evolution of Microbial Communities" featured in-person lectures with remote participation for the first time in Kohn Hall

Mixing Massive Stars

New research reveals hidden processes at work in the hearts of large stars

COURTESY IMAGE

KITP Postdoctoral Scholar, May Gade Pedersen

Astronomers commonly refer to massive stars as the chemical factories of the Universe. They generally end their lives in spectacular supernovae, events that forge many of the elements on the periodic table. How elemental nuclei mix within these enormous stars has a major impact on our understanding of their evolution prior to their explosion. It also represents the largest uncertainty for scientists studying their structure and evolution.

A team of astronomers led by KITP postdoctoral scholar May Gade Pedersen have now measured the internal mixing within an ensemble of these stars using observations of waves from their deep interiors. While scientists have used this technique before, this paper marks the first time this has been accomplished for such a large group of stars at once. The results, published in Nature Astronomy show that the internal mixing is very diverse, with no clear dependence on a star's mass or age.

Stars spend the majority of their lives fusing hydrogen into helium deep in their cores. However, the fusion in particularly massive stars is so concentrated at the center that it leads to a turbulent convective core similar to a pot of boiling water. Convection, along with other processes like rotation, effectively removes helium ash from the core and replaces it with hydrogen from the envelope. This enables the stars to live much longer than otherwise predicted.

Astronomers believe this mixing arises from various physical phenomena, like internal rotation and internal seismic waves in the plasma excited by the convecting core. However, the theory has remained largely unconstrained by observations as it occurs so deep within the star. That said, there is an indirect method of peering into stars: asteroseismology, the study and interpretation of stellar oscillations. The technique has parallels to how seismologists use earthquakes to probe the interior of the Earth.

"The study of stellar oscillations challenges our understanding of stellar structure and evolution," Pedersen said. "They allow us to directly probe the stellar interiors and make comparisons to the predictions from our stellar models."

Pedersen and her collaborators from KU Leuven, the University of Hasselt, and the University of Newcastle have been able to derive the internal mixing for an ensemble of such stars using asteroseismology. This is the first time such a feat has been achieved, and was possible thanks only to a new sample of 26 slowly pulsating B-type stars with identified stellar oscillations from NASA's Kepler mission.

Slowly pulsating B-type stars are between three and eight times more massive than the Sun. They expand and contract on time scales of the order of 12 hours to 5 days, and can change in brightness by up to 5%. Their oscillation modes are particularly sensitive to the conditions near the core, Pedersen explained.

"The internal mixing inside stars has now been measured observationally and turns out to be diverse in our sample, with some stars having almost no mixing while others reveal levels a million times higher," Pedersen said. The diversity turns out to be unrelated to the mass or age of the star. Rather, it's primarily influenced by the internal rotation, though that is not the only factor at play.

"These asteroseismic results finally allow astronomers to improve the theory of internal mixing of massive stars, which has so far remained uncalibrated by observations coming straight from their deep interiors," she added.

The precision at which astronomers can measure stellar oscillations depends directly on how long a star is observed. Increasing the time from one night to one year results in a thousand-fold increase in the measured precision of oscillation frequencies.

"May and her collaborators have really shown the value of asteroseismic observations as probes of the deep interiors of stars in a new and profound way," said KITP Director Lars Bildsten, the Gluck Professor of Theoretical Physics. "I am excited to see what she finds next."

The best data currently available for this comes from the Kepler space mission, which observed the same patch of the sky for four continuous years. The slowly pulsating B-type stars were the highest mass pulsating stars that the telescope observed. While most of these are slightly too small to go supernova, they do share the same internal structure as the more massive stellar chemical factories. Pedersen hopes insights gleaned from studying the B type stars will shed light on the inner workings of their higher mass, O type counterparts.

She plans to use data from NASA's Transiting Exoplanet Survey Satellite (TESS) to study groups of oscillating high-mass stars in OB associations. These groups comprise 10 to more than 100 massive stars between 3 and 120 solar masses. Stars in OB associations are born from the same molecular cloud and share similar ages, she explained. The large sample of stars, and constraint from their common ages, provides exciting new opportunities to study the internal mixing properties of high-mass stars.

In addition to unveiling the processes hidden within stellar interiors, research on stellar oscillations can also provide information on other properties of the stars. This field is proving to be so rich that KITP is now running a long program entitled: "Probes of Transport in Stars" that will bring together over 50 researchers to engage in prolonged discussions of this topic.

"The stellar oscillations not only allow us to study the internal mixing and rotation of the stars, but also determine other stellar properties such as mass and age," Pedersen explained. "While these are both two of the most fundamental stellar parameters, they are also some of the most difficult to measure."

~ Harrison Tasoff, Science Writer, UCSB Public Affairs

Honoring KITP's Leading Philanthropic Investors

Introducing beautiful new donor signage at Kohn Hall and the Munger Physics Residence

We are incredibly grateful to the generous donors who have contributed to KITP's endowment campaign so far. A list of spaces named in their honor are below:

Babu Interaction Alcove
Brown Conservatory Garden
Castagnola-Hunter Tower Room
Glenn's Game Room
Gurley Courtyard
Fred Kavli Auditorium
Mitchel Foyer
Ridley-Tree Library
Simons Amphitheater
Troxel Wine Cellar

Fred Kavli

FRED KAVLI (1927-2013), a Norwegian-American, physicist, entrepreneur and philanthropist, was a champion of science who held the deep conviction that scientific discoveries have positive long-term impact on human civilization. In 1958, he created the Kavlico Corporation, which under his leadership, became one of the world's largest suppliers of sensors for aeronautics, automotive and industrial applications. In 2000, he established The Kavli Foundation with the mission to support basic science for the benefit of humanity.

"There is an innate curiosity to basic science that I have always greatly admired, as well as long-range benefits that all too often go unnoticed. Indeed, practically everything we touch in our daily lives has been improved or developed through basic research. This includes our understanding of our world, ourselves, and our universe." – Fred Kavli

Not Both, But All

A History of Art at the Institute

The KITP exists in two physical spaces on UC Santa Barbara's expansive campus – Kohn Hall, where physicists collaborate, which enjoys a panoramic view of the Pacific Ocean and Santa Barbara Channel Islands, and the Charles T. Munger Physics Residence, the beautifully appointed building where visiting scientists live during their visit to KITP.

Adorning the walls of both of these buildings was no simple task. The selection of paintings, drawings, photographs, sculptures, and craftwork that would eventually fill KITP's spaces took over two decades. Kohn Hall and the Munger Residence are now home to a collection of over 80 pieces—and the collection is growing.

Local Santa Barbara painter Marcia Burtt, whose art features prominently at KITP's Charles T. Munger Physics Residence, fondly recalls her time as a founding member of the KITP Art Committee, which undertook this considerable task.

"I was always interested in physics even though I'm an artist," she says. "My sister and I both married theoretical physicists."

Burtt and her late husband David Sowle were initially introduced to KITP through Friends of KITP events at Kohn Hall in the early 2000s. At one such event, they ran into friends and longtime KITP supporters Beth and Derek Westen.

Derek was a member of a newly-formed Advisory Council made up of a group of physics enthusiasts chosen by then-director David Gross to assist with fundraising for KITP. Gross was motivated to include art in the initial fundraising push.

"I hate empty walls," He explained, "At my house we have paintings everywhere!"

But the suggestion to the group to consider funding art at KITP did not take off as expected. "Most were totally uninterested in art," he lamented. "I learned over the years that it can be extremely difficult to raise money for art at a physics institute. There is a very small intersection of people interested in physics and art."

MONIE DEWIT

Longtime Friends of KITP Beth and Derek Westen hosted the Friends of KITP annual Gluon Holiday party in 2019

Luckily, the Westens were located at just such an intersection. At Gross's request, Beth Westen agreed to serve as founding member of the KITP Art Committee along with Burtt. They were joined by the late Santa Barbara Museum of Art photography curator Karen Sinsheimer.

HARRISON TASOFF

Former KITP Artist-in-Residence Jean Pierre Hébert next to his dynamic sand and wood sculpture, Ulysses

"It was the three of us, plus David Gross, in the beginning," Burtt said.

The small committee was limited by a budget left over from KITP's original director, Nobel Laureate Walter Kohn. Some of the first pieces at KITP were hung in the temporary space in Ellison Hall before Kohn Hall was built in 1994, but made an impression all the same.

"Walter Kohn had an art budget at KITP; that was something to aspire to," recalls Lee Smolin, one of the first postdoctoral scholars at KITP and a co-founder of the Perimeter Institute in Canada.

The original funds were left over from a generous gift from John and Betty Stephens to pay for the architectural designs for Kohn Hall, but would not be enough to entirely outfit the walls of the institute with the caliber of art that Gross and the committee had envisioned for a world-class physics institute. "That's when I realized to my dismay that I would have to engage in fundraising, not something that I had any experience in or looked forward to," he laughed.

Luckily, the committee thought up an innovative way to fill KITP with art without incurring huge costs. Inspired by similar art programs at Princeton and Fermilab in Illinois, Gross proposed an artist-in-residence position, modeled after the idea of journalist-in-residence programs.

Fermilab's first director, Robert Wilson, eventually led Gross to John Rose, sculptor of the DNA-inspired Odalisque which curves gracefully above visitors as they enjoy daily coffee and cookies in Kohn Hall's commons. Odalisque was the art committee's first purchase, followed by a Calder-inspired mobile and series of ocean wave photographs by Bill Dewey.

In 2003, Beth Westen and Marcia Burtt proposed Jean-Pierre Hébert as KITP's first Artist-in-Residence after Beth saw his work at a small gallery in Santa Barbara. Hébert, with his background in engineering and computer science, pioneered the creation of drawings based on his original code and computer-driven devices.

Burtt had shown his work in her gallery, and excitedly described what drew her to his art. "I loved the obsessive nature of what he does."

"What I wanted was not just random art, but something that was associated with science and physics, if possible," Gross said of his selection process. "Jean-Pierre was great from that point of view; he was very interested in physics and was a conceptual artist. People like Jean-Pierre are not easy to find."

Once chosen as KITP's Artist-in-Residence, the position stuck. "There might have been moments when they thought, 'Well, shouldn't the Artist-in-Residence revolve?" Burtt said, "But Jean-Pierre was so enamored with what he did there that he became almost part of the faculty. We never looked any further."

"We hit it off, and he was fantastic," Gross confirms. "We gave him an office and over the years he was able to take advantage of our computers, as his art is very connected to that." Hébert's computer-generated line drawings, with soft colors and complex, pleasing patterns, soon decorated the walls of Kohn Hall, and his meditative sand and wood construction Ulysses, created with the help of UCSB engineer David Bothman and furniture designer Victor DiNovi, provided hours of contemplation.

When Director Lars Bildsten was faced with the task of finding art for KITP's newly-built Munger Physics Residence in 2015, he returned to Hébert, who created custom pieces to decorate the interiors of visitor rooms (Hébert also created and hand-printed the popular KITP Holiday Card for many years before his passing in March of 2021) and coordinated the recruitment of Hans Dehlinger, Ian Parker, and F. Myles Sciotto to create conceptual pieces for the Residence based on the intersection of art and science.

Marcia Burtt provided recommendations on piece selection and size during the process, and her landscape prints of Santa Barbara and Goleta are interspersed throughout the public spaces and guest rooms. Prints of her good friend and late painter Meg Torbert's abstract work can also be found there, as can many unique pieces from Gary Smaby, a frequent visiting artist who has spent substantial time at the KITP.

Remarking on the importance of providing an inspiring place for physicists to work and live, Burtt recounted an instance on a trip to Europe in which she overheard, with amusement and pride, two hotel guests discussing their recent visit to KITP and the Munger Residence. "It's a thrill to be associated with such a world-renowned place."

Directors at KITP have long understood the fundamental value of connecting the aesthetic world with the scientific one, and Burtt considers it as two sides of the same coin. "Both what I do as a painter and my curiosity about the natural world . . . are all part of the gift of being alive and sentient in this universe," she said. "I see them as different mushrooms growing on the same piece of dirt. You need both – and not just both, but all."

Although the art committee no longer meets regularly, contributions by the original group of four continue to be appreciated by over 1,000 yearly visitors to KITP as well as its faculty, fellows, and staff.

~ Megan Turley,
KITP Development Coordinator

Painter and KITP Art Committee Member Marcia Burtt

On the Hunt for Gravitons

KITP co-founder proposes a new approach in the search for the elusive graviton

Physics has two superb theories explaining our universe. The problem is no one can join them together. Einstein's general relativity describes how physics plays out on the scale of the universe, with gravity as the main actor. Meanwhile, quantum mechanics and the standard model make detailed predictions about the processes at the subatomic scale — predictions that have been verified billions of times in massive particle colliders and detectors.

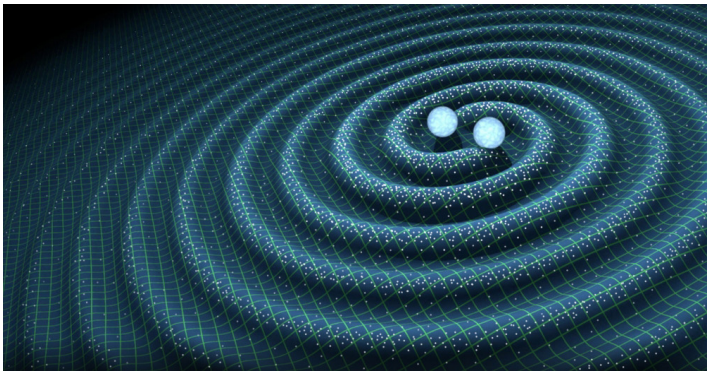
Unfortunately, the two don't mesh very well. One consequence of that: while scientists know of particles associated with the strong, weak and electromagnetic forces, they have yet to discover a particle of gravity, or graviton.

UC Santa Barbara Emeritus physics professor Ray Sawyer has published a paper in Physical Review Letters investigating gravity interacting with electromagnetism from a quantum field theory perspective. The study suggests new directions to explore for clues about how gravity works at the quantum scale, focusing on the behavior of the dense cloud of gravitons that appears near a violent event in space, such as a black hole merger. Some of the gravitons can then transform themselves into very long wave radio waves of possible detectability in the vicinity of Earth.

The article is featured as an Editors' Selection on the journal's web-page.

"The most important result is the possibility of verifying the quantum nature of the gravitational field," said Sawyer. "And that is so significant that you probably don't want to dilute the message with other, subsidiary stuff.

"One reason that question has become of particular interest is that a small but apparently growing fringe of persons are questioning whether gravitons should exist," he continued. "This is a result of frustration over unresolved technical issues in quantum general



R. HURT - CALTECH / JPL

Gravitational waves from merging neutron stars visualized as a surge of discrete particles, called gravitons.

relativity that have extended over generations. I duck these issues by using some classic results from a calculable sector of the theory, results that had been deemed to be correct but too small for experimental confirmation — ever. And my innovations were strictly in the domain of applying these classic results to systems of vast numbers of simultaneously interacting acting gravitons, rather than to two gravitons interacting to form two photons."

Sawyer describes two advances that made his results possible. The first was uncovering a "mean-field instability" in the governing equations. The second was adapting "quantum break" theory, already in use for some localized condensed-matter systems containing scores of atoms in a "Bose Condensate" state. He emphasized that neither step required proficiency in the general theory of relativity. Sawyer also acknowledged his deep debt to the quantum general relativists who in 1975 provided the real basis for the current work. Associated with KITP since it's beginning in 1979, Ray continues to work in Kohn Hall every day.

~ Harrison Tasoff, Science Writer, UCSB Public Affairs

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