Newsletter

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UC SANTA BARBARA
Kavli Institute for Theoretical Physics

The banner image is a photo from our celebration of the naming of the David Gross Commons in Kohn Hall. As KITP's Director for 15 years, David (fifth from left, above) led a remarkable expansion of KITP's activities, while at the same time renewing the faculty and expanding our sources of support. Due to his efforts, KITP now has vigorous programming across all of physics (including astrophysics and quantitative biology), broader support for early-career physicists, and an enlarged Kohn Hall to accommodate the nearly 1000 long-term visitors every year. David's remarkable ability to track a broad range of science and see where KITP could successfully expand its scope is a testament to his deep intellect and ravenous scientific curiosity. David not only recruited me to the KITP as a Permanent Member, but he also enthusiastically convinced me to succeed him as Director. Thank you, David, for your tireless efforts on the behalf of all of science, not only here at KITP, but also across the globe. And, thanks must also go to Jackie Savani (fourth from left, above) for your active support and engagement here at KITP.

In honor of David, Dr. Mani L. Bhaumik (far right, above) made a generous donation to our postdoctoral scholar endowment. Mani has been a remarkably generous supporter of theoretical physics, most notably with the establishment of the Mani L. Bhaumik Institute for Theoretical Physics at UCLA. Mani provided a wonderful quote for David's plaque: "There is no one I know who has done more for the international physics community than David Gross". We were also so happy to have UC Santa Barbara Chancellor Henry T. Yang (second from left, above) and Dilling Yang (third from left, above) with us for the celebration. So much of KITP's success is due to their support of the institute over the last nearly 30 years.

The community of Montecito suffered a terrible disaster in January 2018 when the combination of a fire quickly followed by a dramatic rainfall led to a debris flow event. Lives were lost, homes were ruined, and rebuilding continues to this day. By coincidence, we were running a program at the time entitled: "Physics of Dense Suspensions", which brought together physicists, geo-physicists and fluid dynamicists who study the nature of flow in liquids that contain solid material (e.g. water with suspended sand). The similarities with the debris flow were many, and program participant Douglas Jerolmack (U. Penn) quickly went to Montecito to study what happened there in a collaborative effort with faculty here at UCSB. Please read the article on page 2 to learn their insights.

KITP is a special place for our scientific visitors in many, many ways. One particular aspect is the excellence and dedication of our staff towards the mission of ensuring that our visitors have the most productive stay possible. The article on page 5 highlights Craig Kunimoto, KITP's longest serving staff member. His story tells it all, but, even more, just recently Craig was instrumental in trouble-shooting an IT issue at the Munger Residence that was inhibiting our ability to monitor our hot-water system. Craig continues to amaze us all!

We strive to be at the frontier of physics at all times. For that reason, we remain open to rapidly moving when the physics community identifies a cause to rapidly convene. Prior "Rapid Response Programs" discussed LIGO's discovery of black holes and the experimental realization of twisted graphene layers as platforms for scientific discovery. UCSB Physics Professor Nathaniel Craig identified the need to gather the High Energy Physics community to discuss the challenges posed by a possible Muon Collider. The outcomes of that event are described on page 6. I'm also happy to announce that Nathaniel will be working with us on a five-year Particle Theory Initiative to create new connections across physics.

KITP is now providing a focused 6-8 week visit to KITP for a few faculty members every year who have heavy teaching loads at minority-serving undergraduate institutions. KITP Fellow Louise Edwards from Cal Poly San Luis Obispo was with us early this year, and shares her experience on the back cover. We just selected our second cohort of this program, which continues to be generously supported by the Heising-Simons Foundation.

I close with a sad note. This May we learned of the passing of Professor James Hartle. Jim was one of the UCSB Physics Department "Gang of Four" who won the founding grant from the National Science Foundation that created the Institute in 1979. As a prominent scientist who studied the early universe and general relativity, Jim was a giant in physics. He also continuously supported the success of KITP, both by serving as Director for two years, and in successfully recruiting David Gross from Princeton to join the institute and lead us in so many new directions. Our heartfelt gratitude and sincere condolences goes out to Mary Jo and all of the Hartle family.

- Lars Bildsten, KITP Director

Physics of disaster: How mudslides move

Research by KITP program participants aids our understanding of natural disasters

IMAGES BY DOUGLAS JEROLMACK

In early December 2017, the Thomas Fire ravaged nearly 300,000 acres of Southern California. The intense heat of the flames not only killed trees and vegetation on the hillsides above Montecito, it vaporized their roots as well.

A month later, in the pre-dawn hours of January 9, 2018 a strong storm pelted the barren slopes with more than half an inch of rain in five minutes. The rootless soil transformed into a powerful slurry, churning down a creek-carved canyon and picking up boulders in the rush before fanning out at the bottom and barreling into homes. Twenty-three people died in the disaster.

Could this tragedy have been avoided? What is the tipping point at which a solid slope begins to ooze like a liquid? New findings from a team led by Douglas Jerolmack (U. Penn), apply cutting-edge physics to answer these questions. Their study, published in the Proceedings of the National Academy of Sciences, performed laboratory experiments that determined how the failure and flow behavior of samples from the Montecito mudslides was related to material properties of the soil."We weren't there to see it happen," says Jerolmack, "but our idea was, 'Could we learn something about the process of how a solid hillside loses its rigidity by measuring how mixtures of water and soil flow when they're at different concentrations?'"

MELDING THE THEORETICAL AND THE APPLIED

During the winter of 2018, Jerolmack was at the KITP as a program participant —but not to study mudslides. "It's a place to come and hammer out problems that are frontier topics in physics," he says. "I'm a geophysicist, but I wasn't there to do geoscience. I was there to learn about that frontier physics, especially about the physics of dense suspensions."

Three days after Jerolmack arrived, however, the debris flows occurred. About a month later, when it was safe to do so, Thomas Dunne, a geologist at UCSB and a coauthor on the paper, invited him to collect samples from Montecito.

It was a grim task. Some samples came from the devastated remains of homes, where mud flows from the hillside were strong enough to push massive boulders down creek beds all the way up to—and sometimes through—houses. "By the time we got near

The Thomas Fire charred the hillsides above Montecito in late 2017, setting up conditions for mudslides in early 2018

the mouth of the canyon, it was almost like a phalanx of boulders," Jerolmack says. "Houses were buried to their roof lines; cars were pulverized and unrecognizable."

Taking the samples back to the lab, the researchers' goal was to model how the composition of the mud and the stresses it is subjected to influence when it begins to flow, overcoming the forces that lend substances rigidity, what scientists call a "jammed state."

It wasn't the first time that engineers and scientists have attempted this kind of modeling from field samples. Some studies had tried to simulate conditions in the field by placing shovelfuls of dirt and mud in large rheometers, a device that spins samples rapidly to measure their viscosity, or how their flow responds to a defined force. Typical rheometers, however, only give accurate results if a substance is homogeneous and well-mixed, not like the Montecito samples, which contained various amounts of ash, clay, and rocks.

More high-tech and sensitive rheometers, which measure the viscosity of tiny quantities, can overcome this drawback. But they come with another: samples that contain larger particles—say, rocks in mud—could clog their delicate workings.

"We realized we could take measurements that we knew to be reliable and precise if we used this exquisitely sensitive device," Jerolmack says, "even if it came at the cost of having to sieve out the coarsest material from our samples."

A CLEAR SIGNAL FROM 'DIRTY' SAMPLES

The investigation relied on the expertise of each team member. UCSB postdoc Hadis Matinpour prepared, recorded, and plotted out the first samples and analyzed the composition of natural particles. Sarah Haber, at the time a research assistant at Penn, determined the chemical composition of the materials, including important quantities like clay content.

"We had all this raw data and were having trouble making sense of it," Jerolmack says. "Robert Kostynick, then a master's student at Penn, picked up the project for his thesis and put in a huge amount of legwork and thought to organize, interpret, and try to collapse a lot of the data."

Those contributions leaned on an understanding of cutting-edge physics related to the forces at work in dense suspensions. These include friction, as particles rub against one another; lubrication, if a thin film of water helps particles slide past one another; or cohesion, if sticky particles like clay bind together.

"We had the audacity, or maybe the naiveté, to try to apply some really recent developments in physics to a really messy material," says Jerolmack.

Penn postdoc Shravan Pradeep, who has a deep background in rheology, or the study of how complex materials flow, also joined the team. He pinpointed precisely how the material properties of the soil—particle sizes and clay content—determined its failure and flow properties. His analysis showed that understanding particles' stickiness, measured as "yield stress," and how closely particles can pack together in the "jammed state," could almost entirely account for the results observed in the Montecito samples.

Yield stress can be envisioned by picturing toothpaste or hair gel, Jerolmack says. In a tube, these materials do not flow. Only when a force is applied to the tube—a firm squeeze—do they begin to flow. The jammed state can be thought of as the point at which particles are so crowded together that they are unable to move past one another.

"What we realized was with debris flows, when you're not pushing on them hard, their behavior is governed entirely by yield stress," says Jerolmack. "But when you're pushing very hard—the force of gravity carrying a debris flow down a mountainside—the viscous behavior comes to dominate and is determined by how far the particle density is from the jammed state."

In the lab, the researchers were not able to simulate failure, the point at which a solid soil, constrained by "jamming," transitioned into a moveable mud. But they could approximate the reverse, evaluating the muddy materials mixed with water at different concentrations to extrapolate the jammed state.

With climate change, wildfire frequency and intensity are growing in many regions, as is the intensity of precipitation events. Thus, the risk of catastrophic mudslides isn't disappearing any time soon.

The new findings to predict yield stress and the jammed state can help inform modeling that federal and local governments do to simulate debris flows, the researchers say. "Say, if it rains this hard and I have this kind of material, how fast is it going to flow and how far," Jerolmack says.

And in a more general way, Jerolmack and his colleagues hope the work, which combined theoretical and empirical sciences, leads to more such interdisciplinary approaches. "We can take late-breaking discoveries in physics and actually relate them pretty directly to a meaningful environmental or geophysical problem."

by Katherine Unger Baillie
Senior Science News Officer, University of Pennsylvania

Jerolmack joined Thomas Dunne (foreground) and Doug Burbank of UC Santa Barbara to take samples from the field a month after the mudslides. The scientists used them to understand how the composition of mud influenced the forces required for it to lose its solidity.

KITP's Secret Weapon


KITP

As scientists walk through Kohn Hall, they can easily observe the blackboards and art adorning the walls, as well as their colleagues filling offices and meeting rooms. Repeat visitors often come to recognize more and more familiar faces with each visit, especially those of KITP's dedicated staff, like Systems Administrator Craig Kunimoto who oversees technology services and infrastructure at the institute. Craig has become one of the most familiar, friendly faces in Kohn Hall as KITP's longest-serving staff member of nearly 28 years.

Craig grew up in nearby Goleta when it was still a small, unincorporated community. Across the street from his neighborhood were big, empty fields, which are now where people flock for weekly deals at Costco, and crowds regularly gather on green lawns at Girsh Park. At school, he was an avid swimmer and participated on swim teams all the way through high school.

Craig attended UC Santa Cruz to study computer science, but eventually felt burnt out by his major's emphasis on coding and programming. He discovered he was also interested in psychology, and ultimately graduated with a double-major. To pursue his new passion without giving up the California coastline, Craig headed next to UC San Diego, where he obtained a PhD in experimental and cognitive psychology. He initially sought to stay in academia because he liked research and still got to work with computers. However, as he learned more about the long and arduous road to academic tenure, his plans began to shift.

After achieving his doctorate, Craig returned home to the Santa Barbara area to look for a job. He knew he wanted to work in a science-oriented environment. He had also been familiarizing himself with Linux, a new operating system, which at that time was becoming increasingly popular and opened up more career opportunities. Everything seemed to fall into place once Craig obtained a position at ITP in 1995 working with an operating system much like the one he taught himself how to administer, and where there is no shortage of scientists.

For nearly three decades now, Craig has been at KITP through many significant developments. When he was hired, Kohn Hall had only been built for a year. Ten years later, he attended the dedication of the building's new wing. Nearly thirteen years after that, he took one of the first tours of the Charles T. Munger Physics Residence. Additionally, he has seen the launch of major programs like the KITP Graduate Fellows Program and the Quantitative Biology (QBio) summer course, and has worked with four of the six institute directors.

As KITP's infrastructure and activities have expanded, Craig has taken joy in watching the flow of people grow with it. In fact, he credits the people at KITP as his main reason for staying. "The leadership and staff have always been supportive," he explains, "it feels like you're part of more than a team, it's more like a family." While he appreciates everyone he works with, he is especially thankful for Alina Gutierrez, KITP's Online Talks Coordinator, who has been a huge help in tackling the growing list of projects that Craig previously managed on his own.

No matter how busy Craig may get, it's unlikely to hear him complain. When asked how he de-stresses from work, he responds with ease, "well…I'm not really stressed. There's a lot of stuff I have to do, but I don't feel stressed about it." Being Systems Administrator is a full-time responsibility that requires dealing with a variety of technical challenges at any given time. Still, Craig is always one of the first to offer help to anyone at KITP when he can, without asking for recognition or praise. He has volunteered as the unofficial photographer at events that otherwise wouldn't have been documented. He has stayed late to help his coworkers wrap up conferences or clean-up after events. He quietly and consistently goes beyond his regular duties to ensure the institute runs smoothly, which is why he is often referred to by colleagues as "the secret weapon of KITP."

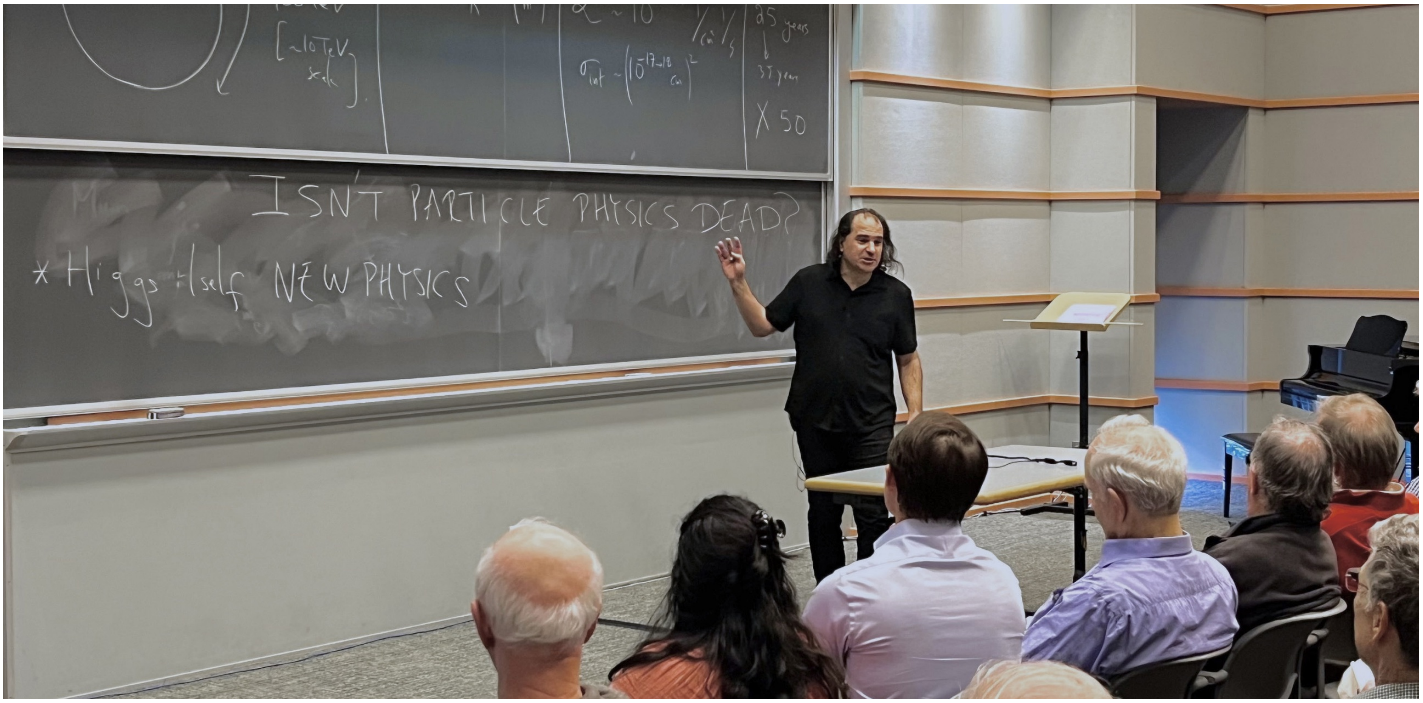
KITP Chief Administrative Officer Lisa Stewart can also attest to Craig's helpful attitude and kindness. She describes him as "a joy to work with, and a steady, solid force at KITP. He is someone that everybody can count on."

KITP boasts that the core of its success and impact on the international scientific community is first and foremost the people, and Craig embodies this strength. "I was so fortunate to find a position at the very start of my career that matched my skills and interests so well, with people I enjoy working with. I can't imagine working anywhere else."

by Demi Cain
Development Coordinator, KITP

A Muon Accelerator

Physicists gather at KITP to chart a path for the next kind of particle collider



HARRISON TASOFF

Although the LHC only discovered one new particle, "particle physics isn't dead," physicist Nima Arkani-Hamed of the Institute for Advanced Study exclaims in the program's packed final talk.

The most powerful particle collider lies about 100 meters underground, circling several French and Swiss towns northwest of Geneva. The Large Hadron Collider (LHC) revs up protons to relativistic speeds, smashing them together so scientists can sift through the debris for evidence of new physics.

But the LHC's grand achievement — the discovery of the Higgs boson — has come and gone, and the collider is reaching the limits of its power output. More discoveries, it seems, will require a new collider. The question is, what type?

Physicists from around the world gathered February 27 through March 10, 2023 at KITP to discuss the potential for a new kind of experiment: a muon collider. This event came on the heels of a formal community discussion effort and aimed to provide concrete recommendations to the two influential panels currently plotting the future of high energy physics in the United States.

"KITP was very happy to host this event," said KITP Director Lars Bildsten. "Not only did it bring the particle physics community together to better understand the challenges, it also triggered debates and discussions that will inform those making recommendations to funding agencies about priorities for large investments."

Proton-proton colliders, like the LHC, can reach high energies due to the proton's relatively large mass. But protons are composite particles — made of three quarks bound together by the strong nuclear force — so their collisions exchange only a fraction of the energy carried in each proton. And they're messy.

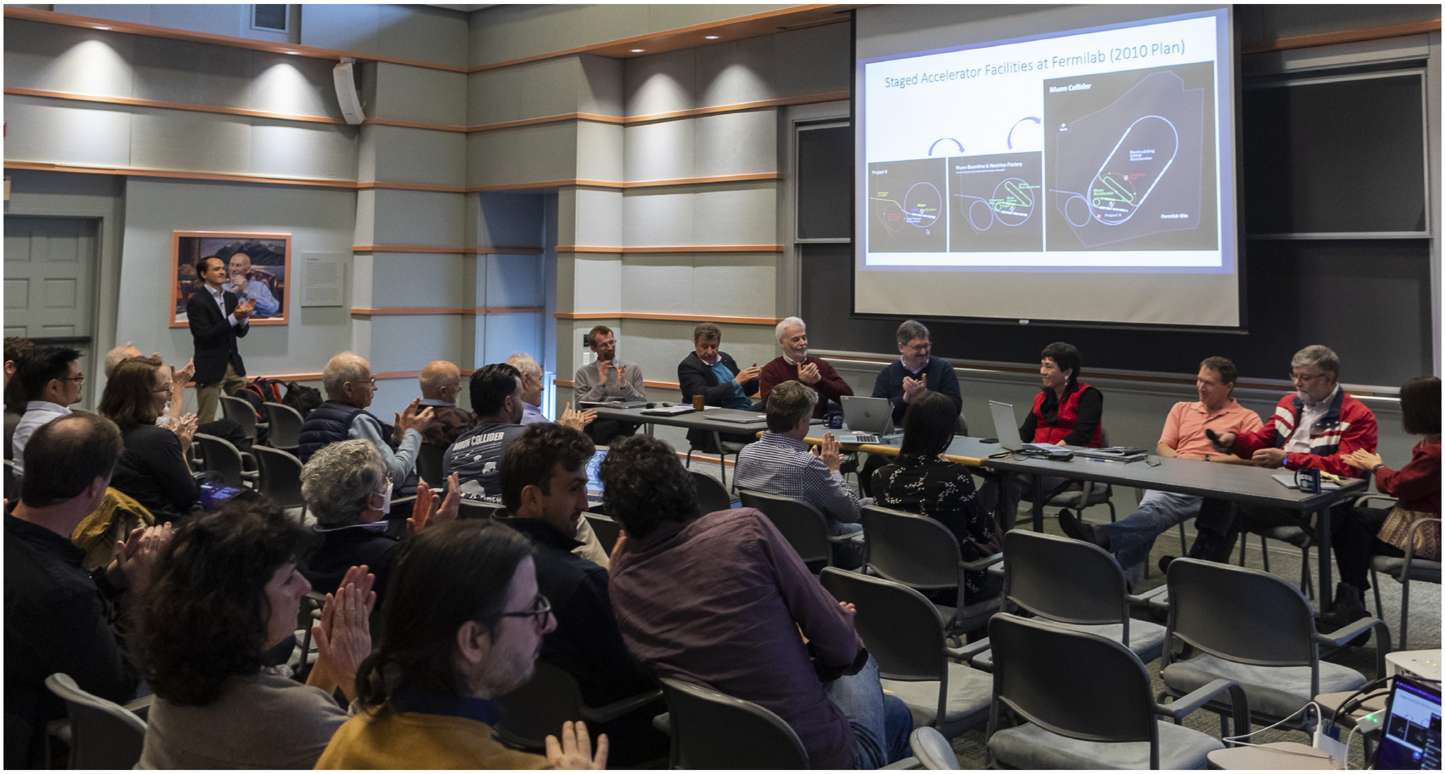
On the other hand, electron-positron colliders are precision machines. Electrons and positrons are elementary particles, and because they are each other's antiparticles, they completely annihilate and convert all of their energy into just a few products. Unfortunately, the small mass of electrons and positrons means they lose a lot of energy during acceleration. Scientists can harness this synchrotron radiation for other purposes, but it prevents electron-positron accelerators from achieving high collision energies.

"The dichotomy is electron-positron machines are for precision and the proton-proton machines are for energy reach," said event co-organizer Nathaniel Craig, a professor of physics at UC Santa Barbara.

Enter the muon, the electron's big brother. "What's exciting about the muon collider is that it can do both of these things at once," explained Nima Arkani-Hamed, a physicist at the Institute for Advanced Study in Princeton, New Jersey. He also presently serves as a member of KITP's Scientific Advisory Board.

At around 200 times the mass of an electron, muons circumvent the issue of synchrotron radiation sapping away energy during acceleration. They are also elementary particles, which means a muon-antimuon collision converts almost all of the particles' energy into something new. So if muons offer so many benefits, why aren't scientists already smashing them together?

Building a functional muon collider faces a litany of challenges. Muons are trickier to make than protons and electrons, and



MATT PERKO

Coordinator Nathaniel Craig of UCSB (standing left) and the Muon Accelerator Panel (right).

focusing them into a beam requires some ingenuity. They also decay in 2.2 microseconds, so physicists need to bring them up to speed quickly in order for relativistic effects to extend their lifespans. This instability also means that muons will decay within the collider, generating particles that smash into the machine's walls and instrumentation. In fact, the decaying muons would generate enough neutrinos — ethereal particles that rarely interact with other matter — that they could pose a minor radiation concern where they pass through the Earth's surface.

Fortunately, scientists have made immense progress on these issues over the last decade, to the point where it now seems justified to begin building prototypes. What's more, the possibility of a muon collider has generated real excitement from early-career physicists, exactly the people who would be devoting their careers to such an endeavor.

Scientists from around the country recently gathered for the Community Summer Study in Seattle to discuss the future of high-energy physics in the United States. "There was a very strong voice for muon collider development coming from the community," Craig said. Theorists and experimentalists came to a consensus that this option was probably the best machine to answer the questions they have.

Now the Department of Energy and National Science Foundation have convened the P5 (Particle Physics Projects Prioritization Panel), a slate of experts tasked with recommending a path for particle physics research in the U.S. every decade or so. At the same time, the National Academies of Sciences have appointed a committee to set a long-term vision for elementary particle physics in the country.

KITP's rapid response program aimed to translate interest from the physics community into concrete recommendations to these planning groups. It brought together accelerator physicists, experimentalists and theorists to explore the possibility of a muon collider. "We've now formed the U.S. Muon Collider Coordination Group, which is preparing and organizing input to P5 and the National Academies," Craig said.

A new collider would be a boon to the American physics community. In 1993, the U.S. government scrapped the Superconducting Super Collider, a next-generation facility then under construction near Waxahachie, Texas. "The failure of the Superconducting Super Collider did tremendous harm to particle physics in the United States," Craig remarked. "All of the initiative and momentum has been carried in Europe ever since."

A muon collider offers an opportunity. "You could host it in the United States," Craig said. Indeed, a high-energy collider would fit on the campus of Fermilab in Batavia, Illinois, and make use of all the facilities and resources of one of the country's premier accelerator labs. It could even incorporate infrastructure from the Tevatron, the world's highest-energy collider before the LHC came along. "International cooperation is key," he said. "Wherever it's built, a muon collider would be transformative for particle physics."

by Harrison Tasoff
Science Writer, UCSB Public Affairs

A Fellow's First Winter at KITP Summer Camp

Professor Louise Edwards

When I told my friends about my 8-week visit to KITP, the running joke became that I was at 'physics summer camp'. At first, I was taken aback – did they not realize how much hard work I just put in? But now, I see some similarities.

From my understanding of summer camp, it is fun, you make a bunch of new friends from all over, and you get to explore a new area. That all happened during my 8-week stay at KITP, where I attended two scientific programs (The Cosmic Web: Connecting Galaxies to Cosmology at High and Low Redshift and Building a Physical Understanding of Galaxy Evolution with Data-driven Astronomy) and their associated conferences as a KITP Fellow. What is more - and what I'm not sure most kids get out of summer camp - was that my future years have now taken on a clearer, more purposeful path.

There is one glaring difference, though, and that is the 'summer' part. My visit was from January 30-March 24th, 2023, during probably the most blustery-rainy atmospheric-river-y Santa Barbara weather of the last 10 years! So summer, it was not.

I admit that the first few days were tough. Picture this: at afternoon cookie time, I walk out into the Gurley Courtyard, straight to the coffee. Huge crowd of folks. I don't know anyone. People are already in little clusters. I grab some coffee. I grab a cookie —one won't hurt. I look around nervously, then scamper back to my office. OUFF. That was not my best networking session.

The above experience describes my first few days. But, within a couple of weeks, I connected with a theorist I had lots in common with, and she made the effort to introduce me to her officemate. Not much longer, I was eagerly awaiting the daily cookie times to discuss new ideas, connect folks myself, and generally catch up with my new colleagues.

So, yes. It was like physics summer camp. The time was enjoyable, I made many new connections and even new collaborations, got to see some rockets take off and gave a talk at the nearby Las Cumbres Observatory. Most importantly, the talks I attended, discussions I engaged in, and new resources I acquired have helped me to refine my research questions as I head toward investigating galaxies in upcoming large surveys. I know I want to focus on the local universe's web and take full advantage of the Vera C. Rubin Observatory's Legacy Survey of Space and Time. I know where to go to explore state-of-the-art cosmological simulations that are good comparisons for the real data. Also, I've become a lot more well-acquainted with modern machine-learning techniques that can help explore large datasets (including their benefits and limitations). I left KITP with a pocket full of cosmic questions that I can't wait to answer, and in the end, I didn't even mind the rain.

by Louise Edwards
Associate Professor, Cal Poly San Luis Obispo
2022-2023 KITP Fellow

Participants in the 2023 KITP research program The Cosmic Web: Connecting Galaxies to Cosmology at High and Low Redshift

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